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Modeling switched circuit network systems using PLANITU

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THESIS

MODELING SWITCHED CIRCUIT NETWORK SYSTEMS USING PLANITU

by

Raymond Kenning

December 2005

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13. ABSTRACT (maximum 200 words)

The realization of today's telecommunication networks is a challenging task. Network architectures are constantly changing to meet new requirements for many new and exciting services and applications. As a result of these added new requirements, new types and mixes of traffic profiles are being introduced into these networks. To facilitate these needs, there are many tools which have been developed to aid in the planning, development, optimization and traffic prediction process. One such tool is PLANITU 3.0. PLANITU is designed to handle many types of circuit network systems and features a powerful graphics capability. The software uses well-established, iterative prediction concepts, such as Erlang-B loss equation and the Wilkinson ERT method. Two types of network systems were modeled using real data supplied by Siemens Indonesia. Target networks for study included a fixed switched networks and a GSM (Global System for Mobile Communications) network. PLANITU 3.0 performed well for the fixed switched network systems demonstrating reasonable results within an acceptable degree of accuracy, but performed poorly for GSM systems yielding inoperable simulation features, numerous bugs and software instability.

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MODELING SWITCHED CIRCUIT NETWORK SYSTEMS USING PLANITU

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ABSTRACT

The realization of today's telecommunication networks is a challenging task. Network architectures are constantly changing to meet new requirements for many new and exciting services and applications. As a result of these added new requirements, new types and mixes of traffic profiles are being introduced into these networks. To facilitate these needs, there are many tools which have been developed to aid in the planning, development, optimization and traffic prediction process. One such tool is PLANITU 3.0. PLANITU is designed to handle many types of circuit network systems and features a powerful graphics capability. The software uses well-established, iterative prediction concepts, such as Erlang-B loss equation and the Wilkinson ERT method. Two types of network systems were modeled using real data supplied by Siemens Indonesia. Target networks for study included a fixed switched networks and a GSM (Global System for Mobile Communications) network. PLANITU 3.0 performed well for the fixed switched network systems demonstrating reasonable results within an acceptable degree of accuracy, but performed poorly for GSM systems yielding inoperable simulation features, numerous bugs and software instability.

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To my wife, Amber, the one that has sacrificed the most, I thank you for your love and support through this process.

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EXECUTIVE SUMMARY

The realization of today's telecommunication networks is a challenging task. Network architectures are constantly changing to meet new requirements for many new and exciting services and applications. As a result of these added new requirements, new types and mixes of traffic profiles are being introduced into these networks. To facilitate these needs, there are many tools which have been developed to aid in the planning, development, optimization and traffic prediction process; one such tool is PLANITU [1].

Before a network can be properly simulated, it must be planned accordingly. The planning process includes planning strategies to include planning for the long, medium and short term. Of course, proper planning begins with understanding network requirements. A strict planning process should be developed from requirements and followed accordingly.

PLANITU treats optimization in terms of costs. Networks are arranged in such a way that present users and services will be handled according to the required standards at the least possible cost [1]. The optimization process uses the type of nodes, routing protocol, suitable cables and transmission systems to achieve maximum profit with minimal cost.

PLANITU is designed to handle many types of circuit switched network systems and features a powerful graphics capability [1]. The types of networks the software is capable of handling are fixed rural, fixed metropolitan and the fixed portion of a GSM network [1]. Two types of network systems were modeled using real data supplied by Siemens Indonesia [2]. Target networks for this study included a fixed rural network and a GSM (Global System for Mobile Communications) system.

The software uses well-established, iterative prediction concepts, such as the Erlang-B loss equation and the Wilkinson ERT method [1]. PLANITU uses these formulas and the grade of service in the prediction of call drops and network performance estimations. PLANITU also uses accompanying software, FcMetro and FcRural, for traffic matrix estimation. These programs use a purely statistical approach in an iterative fashion to

create a traffic matrix populated in units of Erlangs. These matrices can then be used by PLANITU for network simulations.

All simulations were conducted on a standard PC notebook with modest hardware specifications. To generate an accurate traffic matrix and construct a working network using FcMetro and PLANITU software, numerous input files consisting of statistical and measured data had to be properly formatted and implemented. All input files were derived from real data collected in 1995 by Siemens Indonesia [2].

Simulation results for FcMetro yielded reasonable network subscriber forecasts for complete areas and sections of areas. Additionally, traffic matrices were generated in four year increments (one for every four years). The accuracy of the matrix is only as accurate as the input data collected.

The Thailand national network simulations generated graphical representations of exchange node locations, network links of highest rate of traffic flow, and network hierarchy. PLANITU was used to calculate the least cost route between exchange nodes depicting the cost in units of MU or monetary unit. The software also displayed the ability to place remote subscriber units (RSU) in the most optimal - maximizing profit and minimizing cost - locations. Other simulations included demonstrations of the network sensitivity. These tests included network reaction to congestion, link failure, route failure and exchange node failure. Values for traffic offered and traffic lost were generated as well as graphical features depicting areas of highest network congestion resulting in calls being blocked.

GSM simulations generated poor results. Many key features did not work, and there were numerous glitches and bugs found during software operation.

Overall analysis of PLANITU 3.0 proved that it is an excellent tool to introduce engineers to network planning; however, software updates and support were discontinued as of June of 2002 [1], which does not make it a realistic tool to use for any real network planning. Future work could include additional GSM modeling with more modern and powerful tools, such as Switch NetWorks or ESG-Netcop [3].

I. INTRODUCTION

A. SYNOPSIS

Realization of today's telecommunication networks is a challenging task. Network architectures are constantly changing to meet new requirements for many new and exciting services and applications. These include soft switches, databases, service controllers, new protocols and interfaces. As a result of these added new requirements, new types and mixes of traffic profiles are being introduced into these networks.

To handle these traffic cases, network planning is critical to the success, development, implementation and continued support of a targeted network. Proper planning is not only critical for just financial reasons, but also for the long term survivability of a telecommunications company. To facilitate these needs, there are many tools which have been developed to aid in the planning, development, optimization and traffic prediction process. This thesis will take an in-depth look at one of these tools, PLANITU 3.0 [1].

PLANITU 3.0 is a tool developed and distributed by the International Telecommunications Union (ITU), Geneva, Switzerland. PLANITU 3.0 is advertised as being fully capable of dealing with new traffic cases and is considered an excellent tool to introduce network engineers to network planning. However, PLANITU 3.0 has not been updated since 10 June 2002 [1]; any real network planning cases should be dealt with using other more powerful and modern tools available on the market [3].

B. OBJECTIVE

The purpose of this thesis is to construct, develop, simulate and analyze a fixed circuit switched network model (Thailand National Network) using real, carefully gathered data supplied by Siemens Indonesia [2] using PLANITU 3.0 to facilitate all simulations. In addition, PLANITU 3.0 will be analyzed for use with a GSM (Global System for Mobile Communications) network.

C. THESIS ORGANIZATION

Chapter II introduces the network planning process to include planning strategy, processes, and optimization structures. Chapter III introduces and examines network architectures to include fixed switched networks (Metro & Rural), GSM networks and traffic profiles. Chapter IV looks at traffic characterization and description, introducing the

Erlang-B loss formula, Wilkinson's ERT method, traffic matrix estimation techniques and the concept of "Grade of service". Chapter V deals with specific details of the simulation environment to include equipment used, model descriptions, data requirements, data file formats, and Thailand and GSM network specific data files. Chapter VI presents simulated results and analysis and provides a detailed description to include predicted network capacity, network response to the following cases, overload in traffic, link failure, route failure, and exchange node failure; also included will be a critique of PLANITU performance in the area of fixed and GSM network performance. Finally, chapter VII will consist of conclusions, and future work.

II. NETWORK PLANNING PROCESS

This chapter will introduce the network planning process to include planning strategies, specific planning horizons, such as long and medium/short term, and optimization procedures and processes for PLANITU.

A. PLANNING STRATEGY

Proper strategy is the key to getting the most out of your network planning. If you consider that there are multiple solutions to the many different network architectures that exist, each network planning case has to be analyzed and dealt with by using more than just one planning tool [3]. This tool must also be constantly maintained and updated to stay current with today's changing networks. Telecommunication companies normally use many different tools for network planning purposes. Since PLANITU's last update was 2002 [1]; PLANITU 3.0 fails the continuity test for our case, but it still remains an excellent tool to learn and develop network engineering skills.

In usual circumstances companies rely on the services of the software companies to provide quick updates. According to the last world telecommunication development conference WTDC-02 (Istanbul, March 2002) the planning strategy should consist of the following [3]:

- Analyze the network planning case, taking into account all technical aspects.
- After reaching the best solution in terms of cost and technical validity, look for the appropriate partnership to define a project for the specific network planning case.
- Implementation of the project under the coordination and/or supervision of ITU-BDT.

Figure 2.1 [2] shows how strategic planning is integrated into the planning process. Strategic planning is based on experience, green-field approach – a method of beginning with a green field or a clean slate, a method of starting from scratch – and parametric models. As can be seen from Figure 2.1 input variables consist of a general traffic forecast, traffic patterns, technical constraints, and cost models.

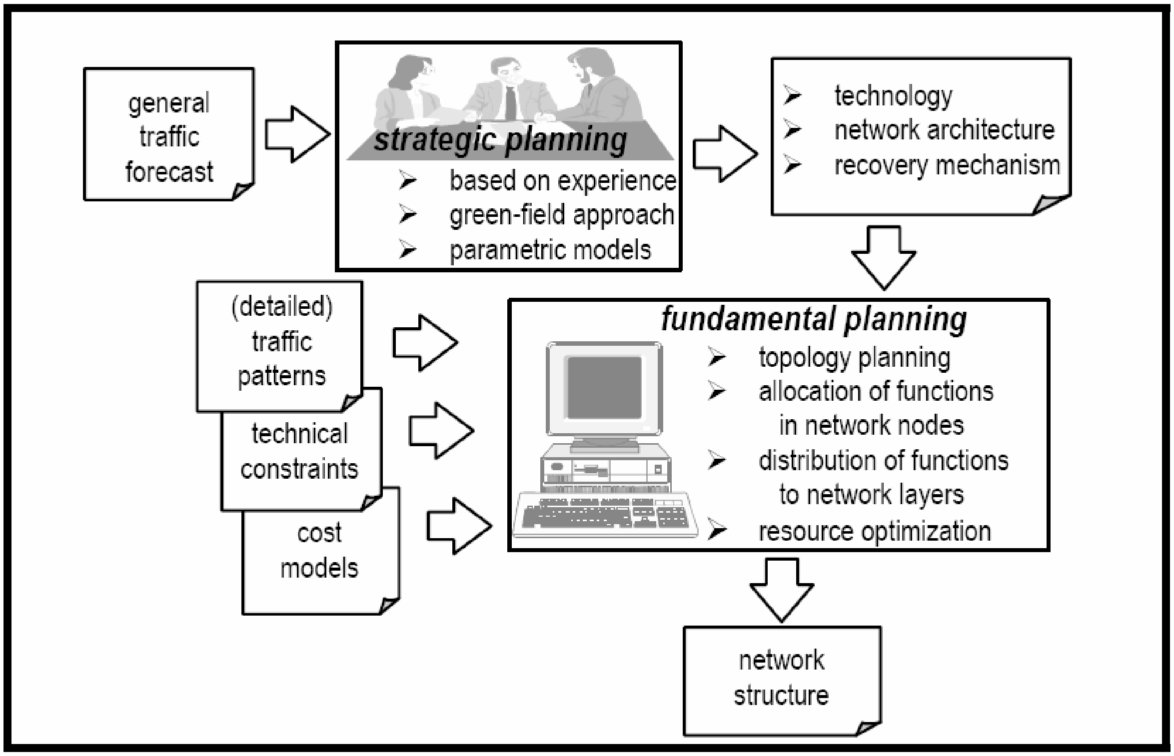

Figure 2.1. The flow of strategic and fundamental planning (from [3]).

B. NETWORK PLANNING PROCESS

There are many factors that must be included in network planning; these factors include anticipated evolution of the network, type of services provided, technologies, the market trend and the regulatory environment [3]. All these aspects must be planned for in order to ensure network capacities, and any associated quality of service promised.

Proper planning should begin with understanding the requirements. These requirements include business oriented (offer new services, increase market share, maximize revenues, reduce capital expenditure, etc.), network oriented (number of nodes, forecast multimedia services, traffic demands, best network architecture and routing), and operational support needs (new operation processes, direct operation, outsourcing, and labor force). All of these requirements must be confronted and met to have a successful plan. Next is an example of a typical network planning tasks list.

The most typical tasks that a planner has to perform to solve and meet the previous requirements are listed below [3]:

- Initial situation analysis for economy, customers, services and network
- Problem partitioning
- Data gathering
- Definition of alternatives per scenario
- Mapping solutions per scenario
- Design, dimensioning, location and costing
- Optimization
- Sensitivity analysis to uncertain variables
- Plan selection and consolidation
- Reporting

Below is a block diagram that shows how the planning process flows with other areas of implementation Figure 2.2 [2].

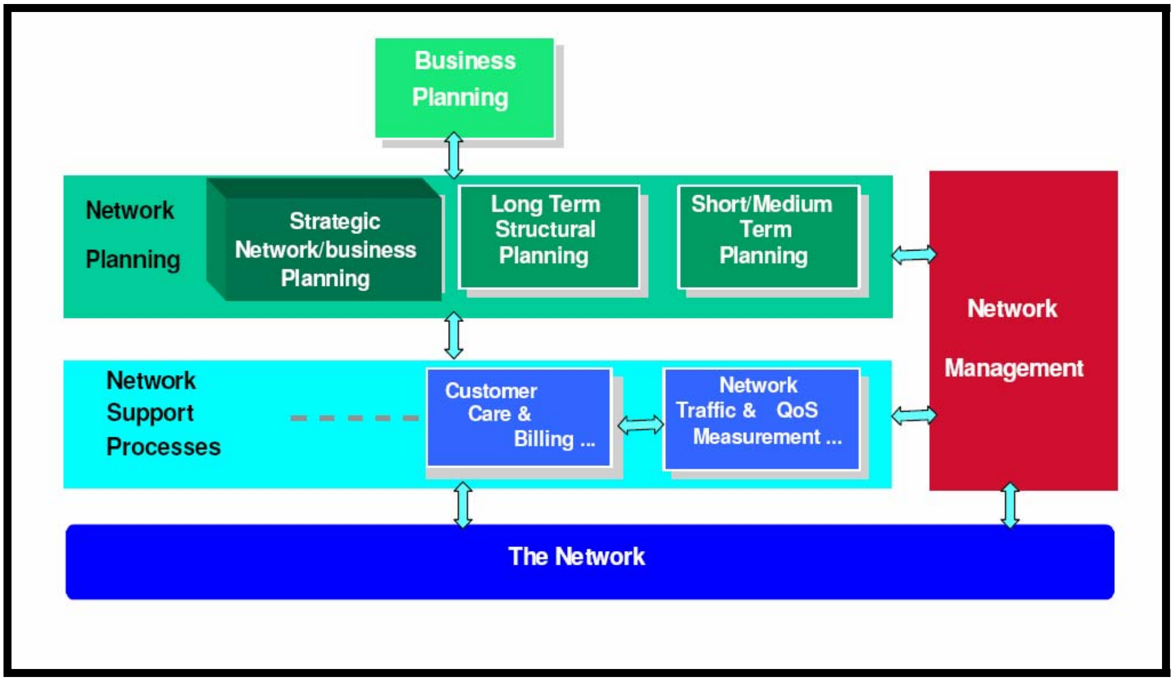

Figure 2.2. A flow chart for the network planning process and its relation to other network activities (from [3]).

Figure 2.2 shows how strategic network planning, business planning, long term structural planning, short/medium term planning have to be applied in an iterative way, it also shows how they must communicate with the related network management and operation support processes. Some examples are traffic measurement, and performance meas-

urements. Next will be a closer look at the differences between long, and medium/short term planning.

Long term planning or LTP is used to define and dimension the network aspects which can be characterized by a long life time and large investments of capital for their deployment [3]. Examples of this are topology, technological decisions and fiber cable capacity. A more concrete example includes the following [3]:

- Location and technological evolution of the network nodes.
- Partitioning into sub-networks.
- Identifying the interconnecting of different domains.
- Establishing the hierarchy between different domains.
- Logical network structure for the network layer.

All input variables that go into a LTP consist of long-term demand forecasts, possible node locations, physical paths for infrastructures, architecture (ring or mesh) and most importantly infrastructure costs. It is also critical that cost calculations should have the same precision as the long-term demand forecasts [3]. A typical timescale for LTP is normally three to five years.

Medium/short term planning or MTP's objective is capacity upgrading of the network nodes and links to follow the LTP deployment strategies of the optical network. After this is completed the MTP's goal is to determine the routing map and node capacities (this is where PLANITU comes in). Typical input variables consist of [3]:

- Network nodes (from LTP).
- Present and potential fiber routes.
- Telecommunications systems in use.
- Installed equipment in each node.
- Forecasted demands for each planning period.
- Component costs to include installation, upgrading and un-installation costs of the different systems.

With proper MTP inputs one can expect to generate results such as detailed routing and grooming for each demand, telecommunications systems to be installed, type of

equipment to be installed, and scaling and possible delays according to budget constraints [3]. A typical MTP time scale should be equal to that for LTP, but should be subdivided into several shorter periods (typically around one year each phase) [3]. It should also be noted that MTP and LTP should be adjusted and or repeated each time the demand for service forecast changes dramatically (also where PLANITU comes in).

Figure 2.3 [3] shows how long term and medium/short term planning all come together in a complete network. The bottom two layers are LTP and the top two represent MTP.

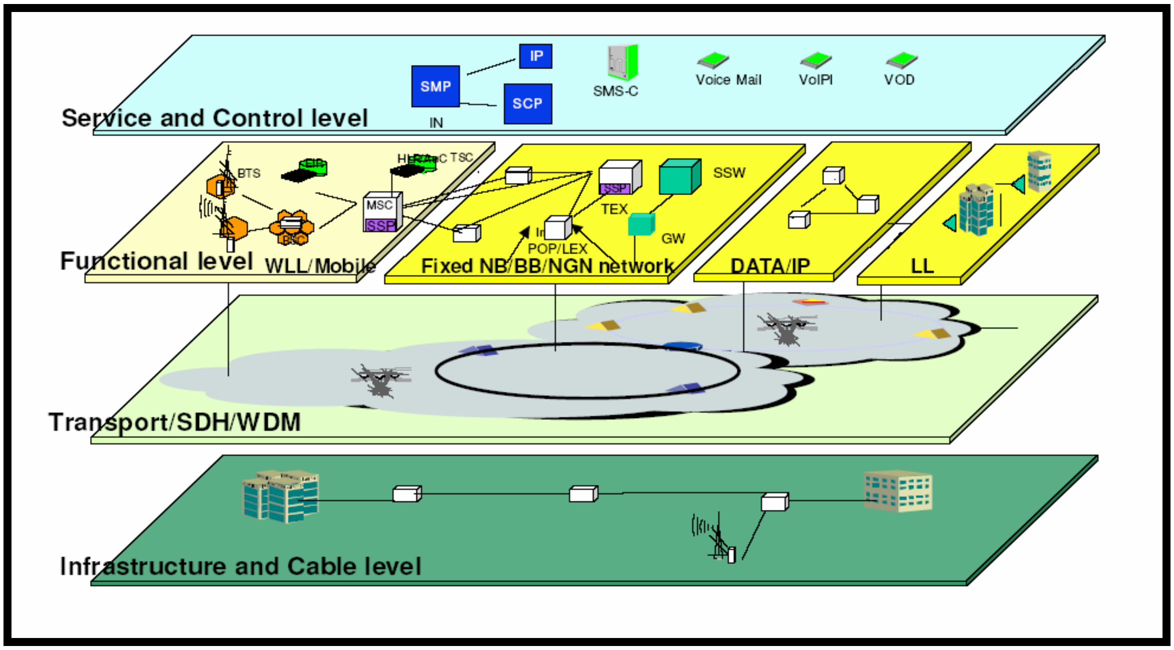

Figure 2.3. Network layer modeling for planning and design (from [3]). The upper two layers reflect MTP while the lower two layers are related to LTP.

C. NETWORK OPTIMIZATION

Thus far the planning strategy and network planning process development has been the focus. This section will deal with network optimization and how PLANITU is at the center of this.

PLANITU treats optimization in terms of costs. What this means is that PLANITU will arrange a network in such a way that present users, and services will be handled according to required standards at the least possible cost [1]. It should also be understood that the network should be designed and optimized to be flexible, simple and

extremely robust in nature. In order to run PLANITU, input data files must be carefully constructed using data that is as accurate as possible; chapter V will go into this process in further detail.

To optimize a network, PLANITU uses topologys, the type of nodes, routing protocol, suitable cables and transmission systems. This is done by defining the remote subscriber units or RSU, access switches, the type of cables chosen and the type of transmission system. Other areas to define include areas to service, position in hierarchy, and how traffic streams should be split over direct routes [1].

Within the course of optimizing, PLANITU does dimensioning by performing calculations within many specialized sub-routines, these are done by iterative loops. If a network configuration is optimized and dimensioned and another new exchange node is introduced somewhere within the network, PLANITU will perform a completely new iteration with the updated data. Figure 2.4 [1] shows PLANITU's optimization process as it goes through its iterative process.

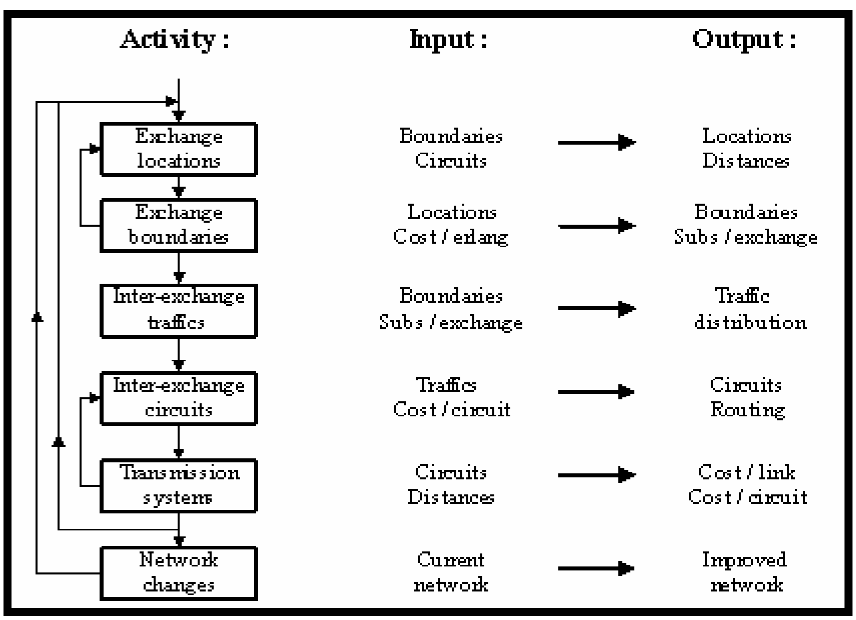

Figure 2.4. A high-level perspective on the iterative procedure for network optimization (from [1]).

The flow chart above shows the main steps of PLANITU's iterative procedure for optimization. Each box represents the main calculation and optimization within the program. The arrows show the sequence of activities that will follow. The first loop back is

between exchange locations and exchange boundaries. There is a strong interaction between the two and it must continue to have sub-iterations until a stable solution is reached. This is also true for inter-exchange circuits and transmission systems. If we take a deeper look into the block exchange locations and exchange boundaries from Figure 2.4 we see a whole additional iterative model (see Figure 2.5 [1].) This model has input data which consists of geographical area, subscriber inventory; exchange and remote subscriber switch specification, routing constraints, grade-of-service plan, transmission plan, signaling requirements, traffic demand, switch costs, transmission costs and technical properties. By using this input data with this model the user can expect to receive the optimal number and location of exchanges and remote subscriber switches, optimal boundaries between exchanges, remote subscriber's switches and between exchanges and remote subscriber switches [1].

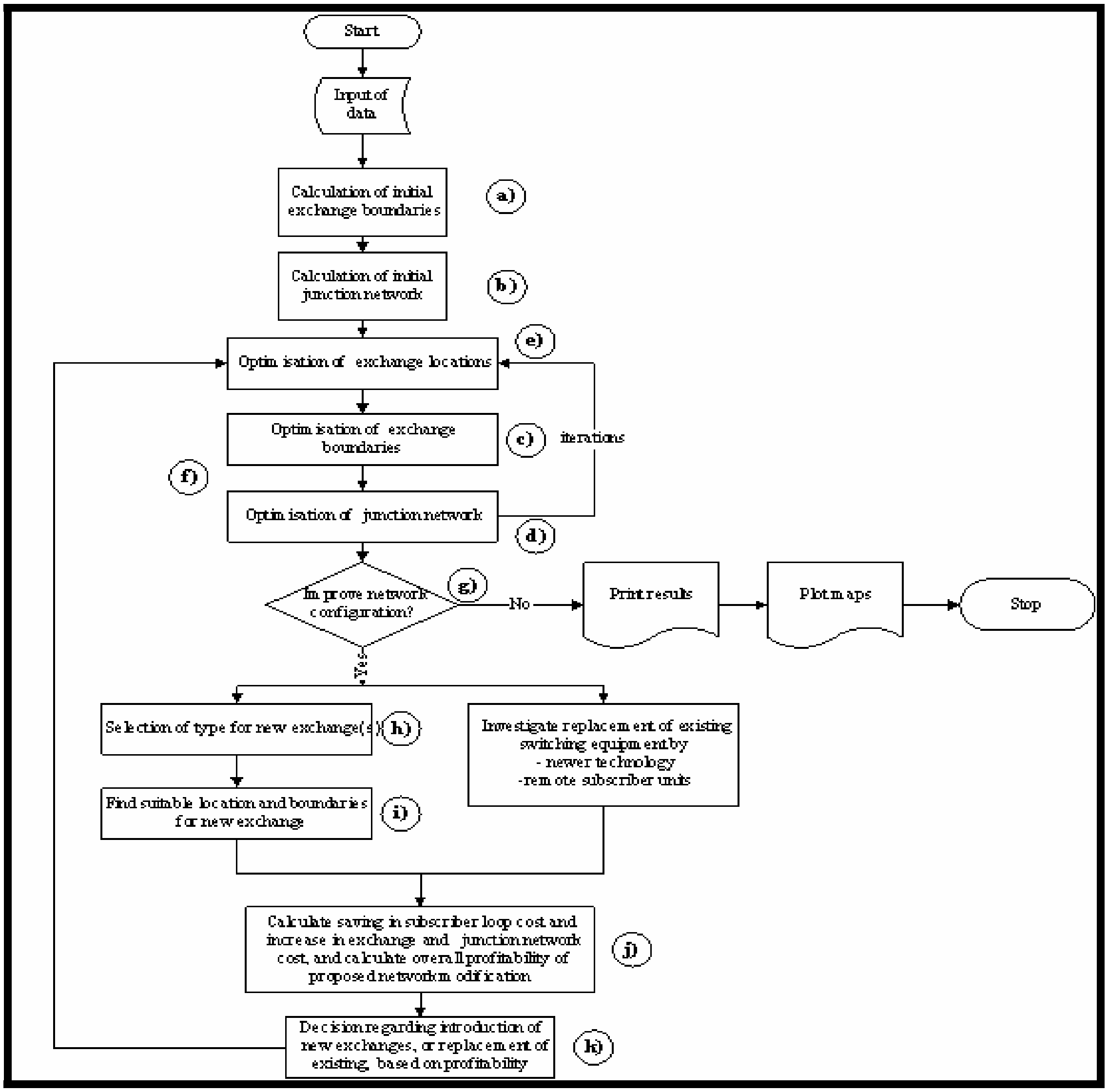

Figure 2.5. An illustration of the optimization process showing the sequence of events of the iterative process for switching unit location placement (from [1]).

To follow what is exactly going on in Figure 2.5 [1] it is necessary to do an iteration trace. Below we can follow the steps [1]:

a) **Calculation of initial borders –** This process accepts the number of exchanges given by the input file; it then calculates the area boundaries without using the effect of the junction network. It basically does a geographical division into exchange areas with the shortest distance criteria.

b) **Calculation of initial junction network –** This process is an iterative procedure in itself. It is done by calculating the following:

- Calculation of distances between exchanges.

- Choice of transmission media based on calculated distances.
- Calculation of traffic interests between exchanges.
- Optimization of high usage routes.
- Overflow traffic, mean and variance is calculated and summed by using Wilkinson's ERT[1]-method
- Reevaluating transmission media choice by including economic factors.

c) **Optimization of borders –** This process temporarily assumes fixed exchange locations; the cost function is minimized connecting subscribers to the exchange using the least cost criteria.

d) **Optimization of junction network –** This process creates a new calculation of traffic interests between the exchanges.

e) **Optimization of locations –** This process temporarily assumes fixed areas; the cost function is minimized by using optimal coordinates for each exchange. The cost function is comprised of the distance-dependent cost of cable connecting subscribers to the exchange and to the transmission media between the exchange and other exchanges.

f) **Optimization of borders and optimization of the junction network –** A repetition of steps c) and d) for greater accuracy.

g) **Introduction of new exchanges –** This is a process of introducing new exchanges into the network. Of course this should only be done if it decreases the total cost of the network itself.

h) **Calculation of possible new locations –** This process finds all intersection points of the boundaries.

i) **Approximate calculation of borders for and location of new exchanges –** This process approximates the optimal location, and optimal boundaries for a new exchange until the location become stable.

j) **Approximate calculation of effect on junction network of new exchange –** This process calculates the gain in the subscriber network and the cost increase in the junction network for all new exchange entries.

[1] A random theory method that assumes a number of traffic streams, characterized by their individual mean and variance, are offered to a common Erlang loss system consisting of a number of channels. This will be covered in more detail in Chapter IV.

k) **Choice of new locations –** This process arranges the possible new exchanges in a sequence with decreasing total gain values and temporarily those locations which are close to the core profitable sites. This procedure also continues to find the best location for new exchanges with in the exchange areas and junction area.

Next discussed is the final part of the iteration model the optimization of the inter-exchange network.

This portion of the iterative model deals with blocks "inter-exchange traffics" and "inter-exchange circuits" from Figure 2.4. This model has input data (see Figure 2.6 [1]) which consists of the physical network layout, locations of exchanges, exchange specification, routing constraints, grade-of-service plan, transmission plan, signaling requirements, traffic demand, switch costs, transmission costs and technical properties. Once again it is necessary to trace through this iterative model to completely understand what is going on [1]:

a) **Calculation of initial marginal costs –** This process is based on the concept of "marginal cost", this cost can be broken into two parts; transmission cost; the cost of one cable pair, one channel, or a multiplex system, this can also be dependant on the number of circuits in the route, the transmission plan, the signaling requirements and the distance between exchanges and switching costs (the cost of exchange equipment for a additional line).

b) **Initial optimization of high-usage routes –** This process solves the partial derivatives of the number of lines on the tandem routes, with respect to the mean traffic on these routes, this of course is not know on the first iteration, multiple iterations must be completed to get a good approximation.

c) **Calculation of overflow traffic, mean and variance –** After optimization this process calculates the mean and variance of the overflow traffic for each route.

d) **Dimensioning of final routes –** This process uses the Wilkinson's ERT method to complete the final route dimensioning.

e) **Optimization of transmission media and physical routing of circuits –** This iterative process selects the most economical path for each circuit group based on cost per circuit per link. It adds circuits to links accordingly, selects the most eco-

nomic combination of transmission media for each link, calculates the cost per circuit for each link and repeats the process until it reaches a stable position.

f) **End of iteration process –** This process compares the number of iterations to the cost reduction between the two consecutive iterations, if the number of iterations is greater than the previous defined values, then the iteration process ends.

g) **Calculation of new marginal costs –** The choice of new transmission media on some routes implies that new marginal costs have to be calculated.

h) **Optimization of high-usage routes –** In this process the high-usage routes have to be re-optimized. This must be done on the basis that the utilization of the tandem routes the transmission media, and the marginal costs and the availabilities could have been changed since the previous calculation.

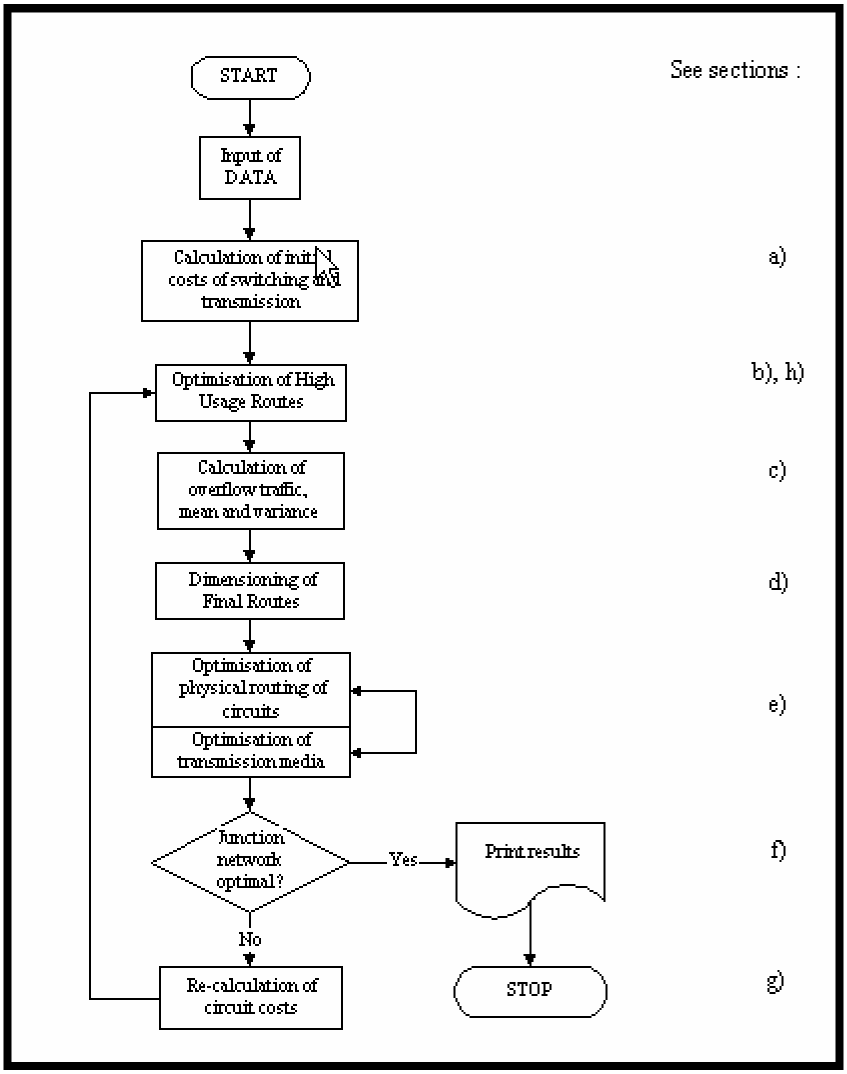

Figure 2.6. An illustration of the optimization process for inter-exchange networks (from [1]).

D. CHAPTER SUMMARY

This chapter covered the process of network planning. Areas covered included planning strategy, planning processes, and optimization procedures and processes for PLANITU 3.0. The next chapter will cover different circuit switched network architectures as well as the differences between a fixed metro and a fixed rural network. Also covered will be a GSM or mobile network architecture. Chapter III will also include typical traffic profiles and an introduction to the concept of a traffic matrix.

III. NETWORK ARCHITECTURES

In this chapter, network architectures will be the area of focus. The different network structures focused on will include fixed metro and fixed rural. This will be followed by an introduction to a GSM mobile network and how it is treated in PLANITU. Finally, traffic profiles associated with switching networks and an introduction to traffic matrices will be covered.

A. FIXED SWITCHING NETWORKS

A fixed telecommunications network is basically a structure that exchanges information over short and long distances. This network provides services to end users in exchange for a subscription fee of some sort. The most basic switched network system looks like Figure 3.1 [1].

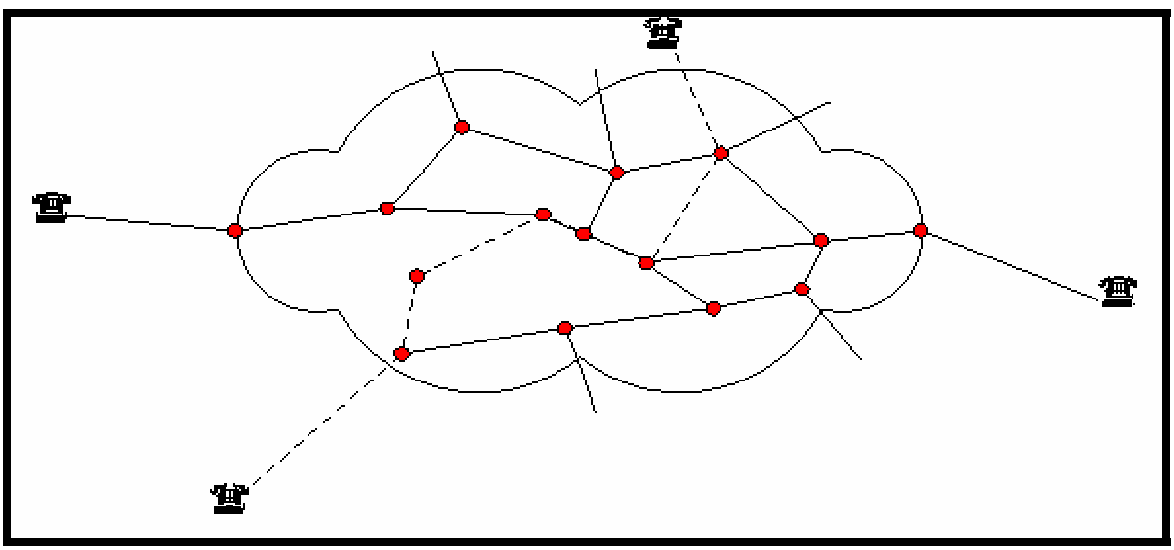

Figure 3.1. A basic switched network comprised of nodes and links. The dotted lines represent two connections through the network (from [1]).

Figure 3.1 is composed of exchange nodes (red nodes), links (connections), and end users (phones). The dotted lines indicate a connection. One observation made from Figure 3.1 indicates that several connections may use the same or partial links at the same time. To accommodate this circumstance, each link must have multiple channels. Also each node must be able to select links in order to set up the best virtual circuit possible taking into account shortest route, lowest cost and the grade of service. To accomplish

this task the nodes must be able to co-operate with other nodes to analyze and utilize address information. Next is a discussion of three different concepts of a switched network structure.

Figure 3.2 [1] shows examples of three different structures. The small circles represent nodes, dots represent central exchange nodes, and lines represent links.

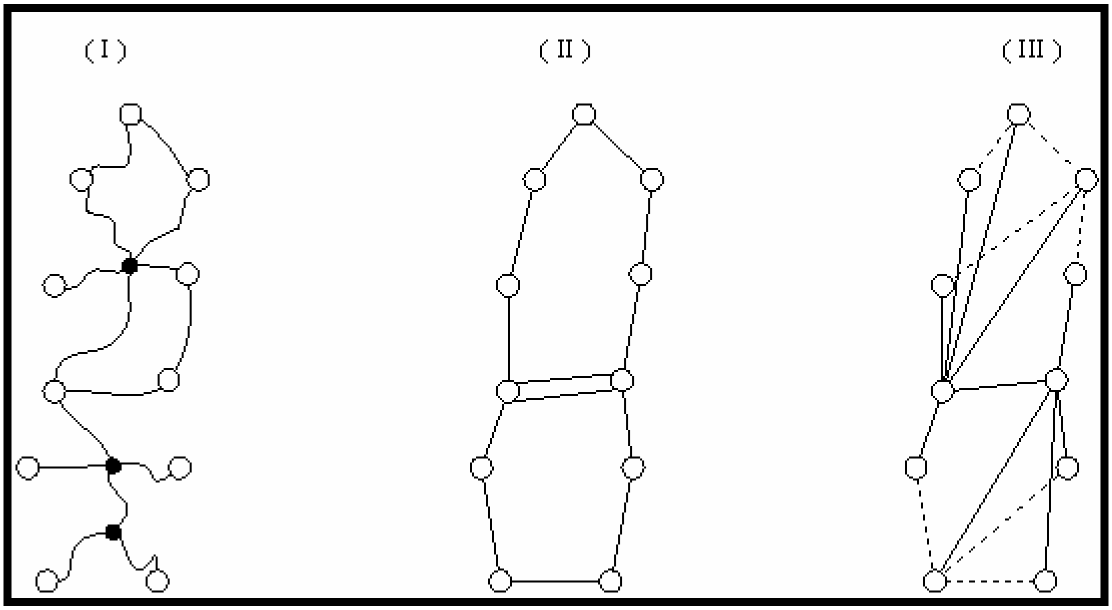

Figure 3.2. Three different network structures; circles represent nodes, full or dotted lines are links (from [1]).

In Figure 3.2 all three structures have the same number of nodes, except (I) which has three additional central nodes. What is interesting is that all three structures describe the same telecommunications network, but demonstrate different concepts. For example structure (I) represents the geographical structure, a representation of the exact geographical map of the service area. The links can be cables, radio relays or fiber, and nodes are buildings and branching points. Structure (II) represents the physical structure of the network, showing the transmission resources. The links are transmission systems, and the nodes are main distribution frames, multiplexers, and cross connects. Structure (III) is the logical structure. The links are traffic routes and the nodes are switches. The full lines are low-loss routes and the dotted lines are high-usage routes [1]. All three structures are included in a PLANITU investigation and have to be included in the input

data. Next is a description of the types of switched network systems PLANITU was designed for and how they fit together.

The two types of networks that PLANITU is primarily used for are rural and metropolitan network systems. The differences between the two can be seen in Figure 3.3 [1].

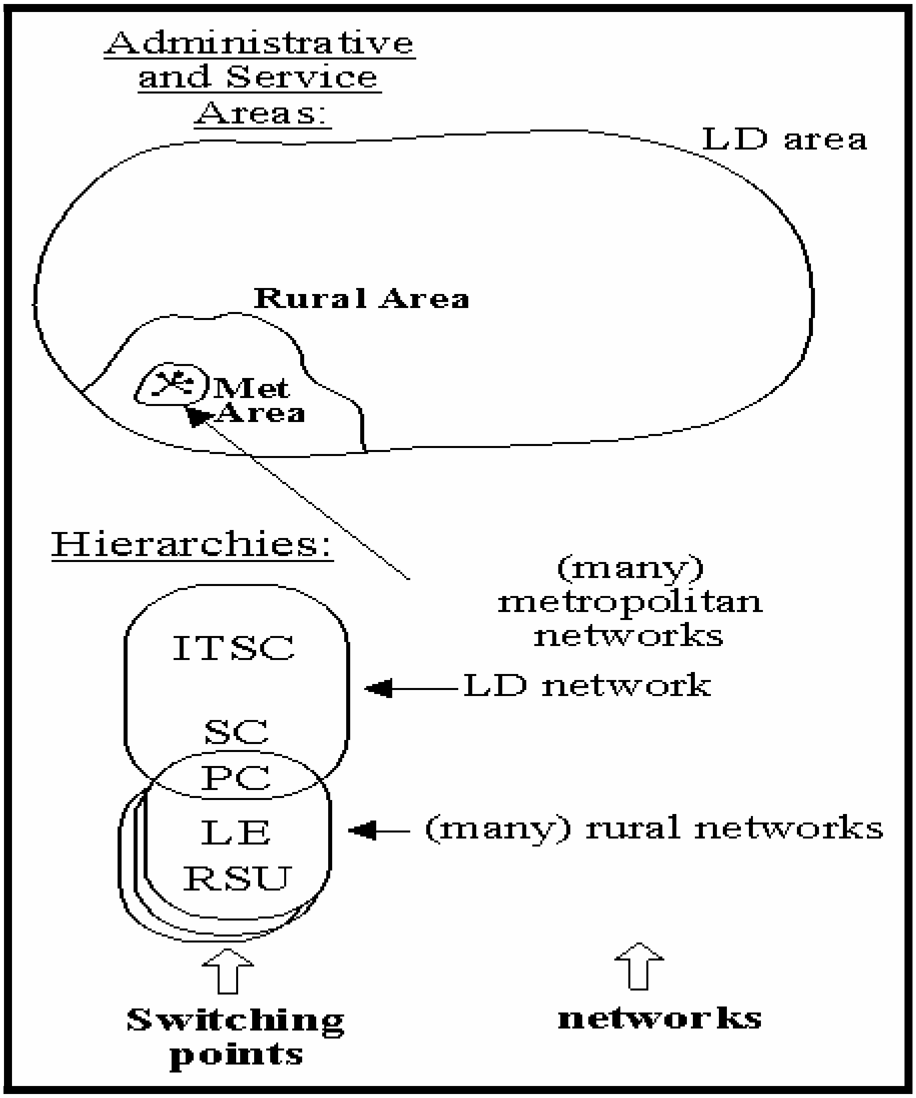

Figure 3.3. A network hierarchy from a telecom view point. The following abbreviations are use in the figure, (RSU) remote subscriber unit, (LE) local exchanges, (PC) primary centers, (SC) secondary centers, (ITSC) international switching centers, (LD) long distance (from [1]).

In Figure 3.3 [1] we see that a rural area network is higher up in the hierarchy than the metropolitan. A rural area would consist of hundreds of towns and villages.

Nodes would coincide with towns and villages, and links would follow along road sides. Subscriber concentration would lie in the towns where exchanges, cabinets and RSU's (remote subscriber units) would be deployed [1]. The network would be subdivided into communes see Figure 3.4 [1].

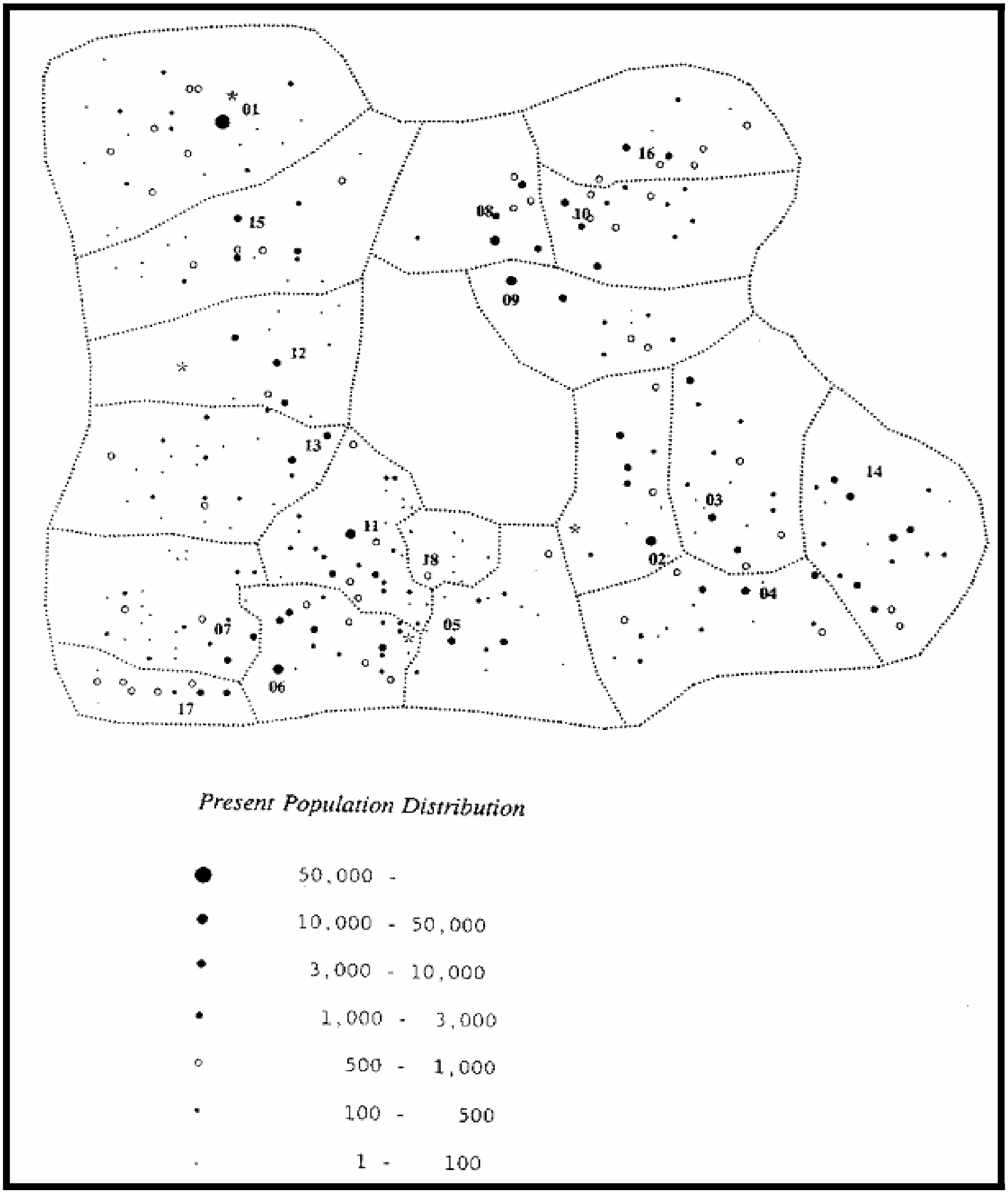

Figure 3.4. A typical rural area –a district- with towns and villages, subdivided into communes (from [1]).

In a Rural area, within each commune would be a commune center. It is here you would find an exchange node. Often between commune centers is where you would find a higher intensity of traffic, while at the same time there would be much less traffic intensity between smaller towns and villages. As a result of these traffic intensity differences a mesh or star type topology is used between commune centers, while the network between the commune centers and other towns and villages would be a tree type (see Figure 3.5) [1].

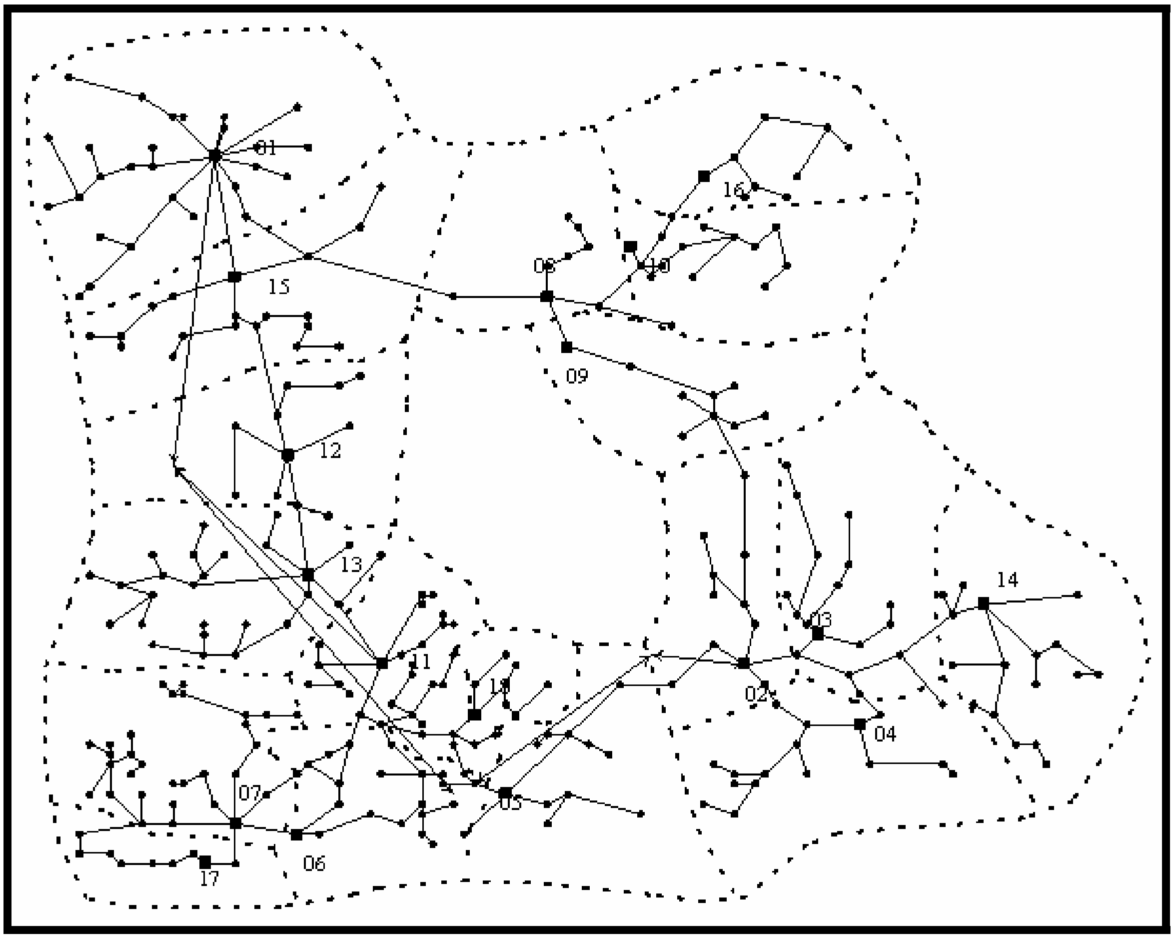

Figure 3.5. Same area as in Figure 3.4, but now showing nodes and links. Note that the commune centers are interconnected (from [1]).

The metropolitan network would be a network set up in a highly concentrated area of population, such as a large city. The structure would be completely different. Links would still follow roads, but exchange nodes could be placed anywhere. Since

subscribers can be located all over a metropolitan area it should be divided up into three sub-areas; basic zones, traffic areas and exchange areas (see Figure 3.6) [1].

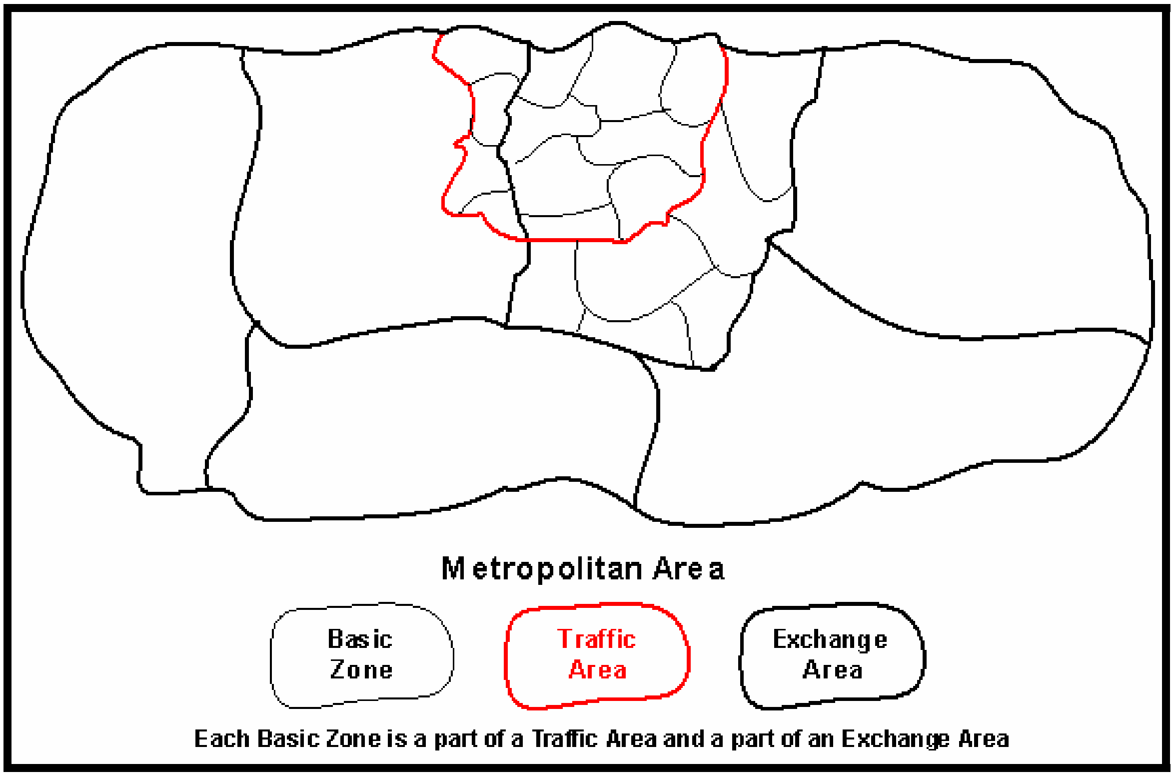

Figure 3.6. A illustration demonstrating how basic zones, traffic areas and exchange areas relate in a metropolitan area (from [1]).

A basic zone is considered a few blocks of apartment houses or resident neighborhoods. The basic zone is very homogeneous in nature in terms of subscribers and their distribution; this also leads to homogeneous traffic intensity [1]. Traffic areas and exchange areas are built from basic zones and are also for traffic intensity purposes considered homogeneous in nature.

Overall a country is subdivided into districts and communes, and places are categorized as the capital city, district centers, commune centers towns and villages. The target model of this thesis will be a rural model set on a large scale for the country of Thailand. Now that the type of networks that PLANITU was designed for have been discussed, it is interesting to look at another type of network that has just been implemented in this version of PLANITU, the GSM Mobile network.

B. GSM MOBILE SWITCHED NETWORK

New to PLANITU 3.0 is an optimization of the fixed part of a GSM network. This paper will also cover an analysis of this new feature. Before exploring the results of the GSM product it would be helpful to understand what a GSM network is and how it is different from the fixed and rural switched networks discussed previously.

GSM or global system for mobile communications is the standard for digital cellular networks. It provides voice and data services, is fully integrated into the telephone network, and accounts for 71% of the world's digital market and 67% of the world's wireless market [4]. Below in Figure 3.7 [5] we see a base station controller or BSC.

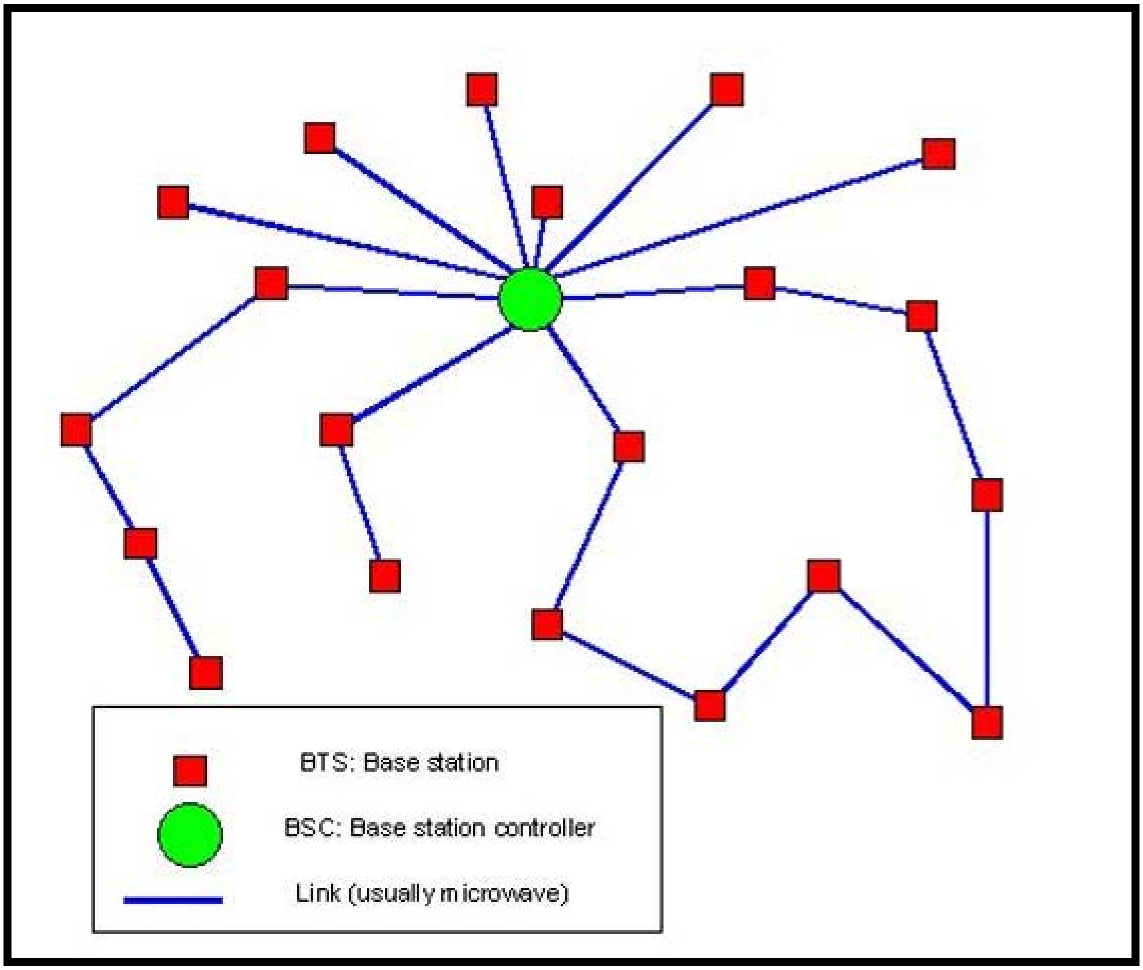

Figure 3.7. A BSC and its associated base stations (from [5]).

The BSC is the basic element of the GSM network; its purpose is to control one or more BTS (red squares). The red squares or BTS are base transceiver stations. They have

a fixed transceiver (tower) that sends and receives signals from and to mobile devices. A single GSM network can cover a major city such as the Dallas–Fort Worth area. Figure 3.8 [3] shows a GSM network infrastructure.

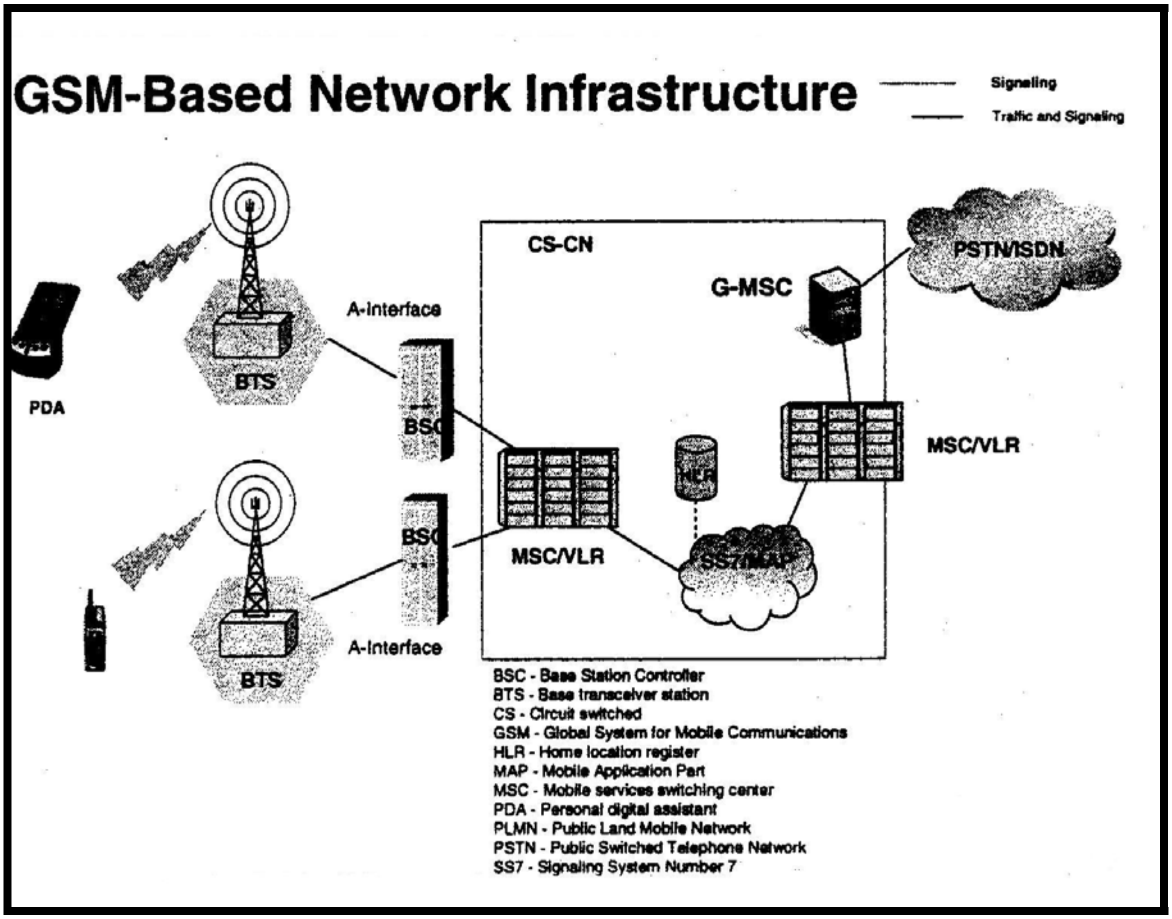

Figure 3.8. An illustration of a GSM network infrastructure showing hand held cellular items interconnected with the network (from [4]).

In order to obtain radio coverage of a given geographical area a number of base stations are normally required. As seen from Figure 3.8 many BSCs come together into a mobile services switching center or MSC. The MSC does two main functions; it coordinates the setup of calls to and from GSM users and controls several BSCs [4]. In order to cover a large area such as the Dallas Fort Worth several MSC's would be required. This is what PLANITU considers the fixed portion of the GSM network see Figure 3.9. PLANITU treats the MSU's as a fixed exchange node.   Here is where we see a problem with using PLANITU for a GSM simulation. It is true that an exchange node and a MSC are quite similar in nature as they both act as switching center circuits, but there are a few

differences. The MSC has to take into account the impact of allocation of radio resources and the mobile nature of the subscribers, in addition procedures must be addressed for location registration and required handover [4]. PLANITU states on page 200 of the users guide that there is no new input data for a GSM model. Analyzing the input files for the GSM model shows that the GSM model is basically a fixed metropolitan network. MSCs are usually kept in a single building to minimize cost. Chapter VI will cover this in more detail.

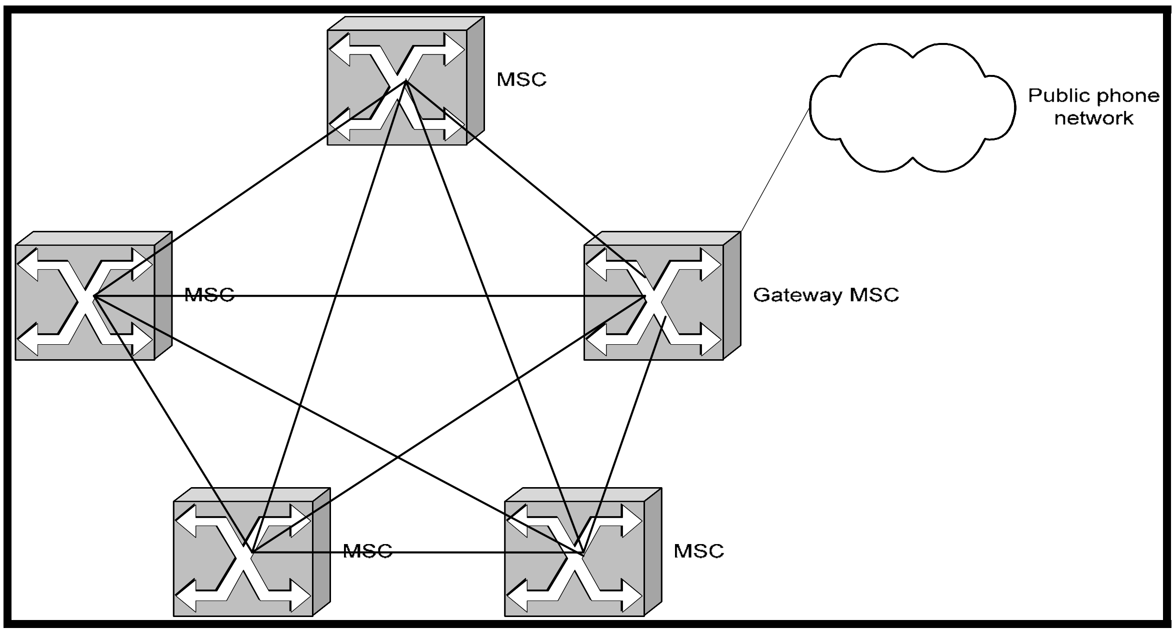

Figure 3.9. An illustration of the fixed portion of a GSM network (MSC connections).

After the MSC comes the gateway MSC. This MSC performs the routing function to the actual location of the mobile station; it also acts as the gateway which connects the GSM network to the public telecommunications network [4]. Now that we know what a GSM network is and how it works it is necessary to touch on network traffic profiles associated with switching network systems.

C. TRAFFIC PROFILES

Telephone traffic varies with the activity of society and how they live. The traffic generated by single independent subscribers tends to be of a stochastic nature with deterministic elements [3]. Careful measurements of calls made during a normal Monday

morning shows the variation in calls/minute in Figure 3.10 [3]. By collecting measurements like these over many days a deterministic curve can be derived (as in Figure 3.11) with superimposed stochastic variations.

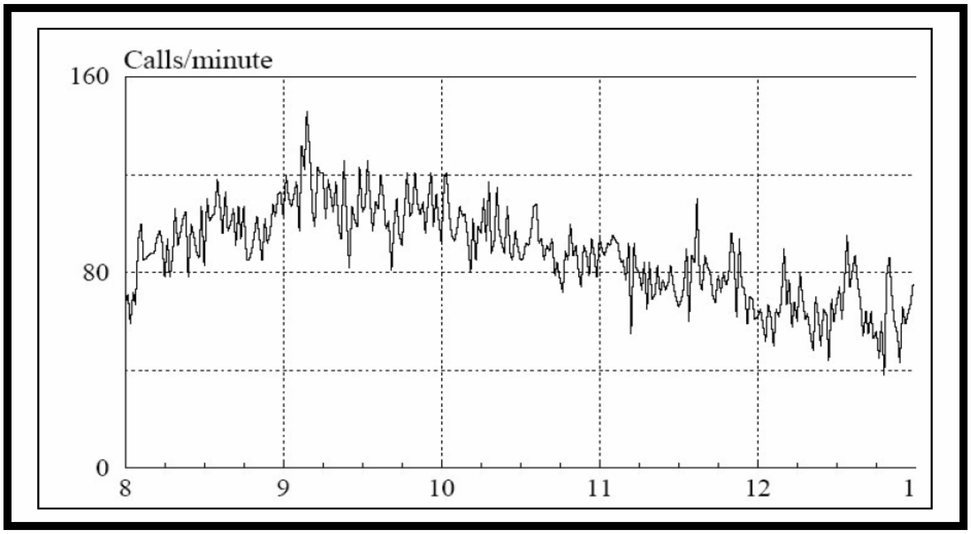

Figure 3.10. An example of the call rate on a sampled Monday morning (from [3]).

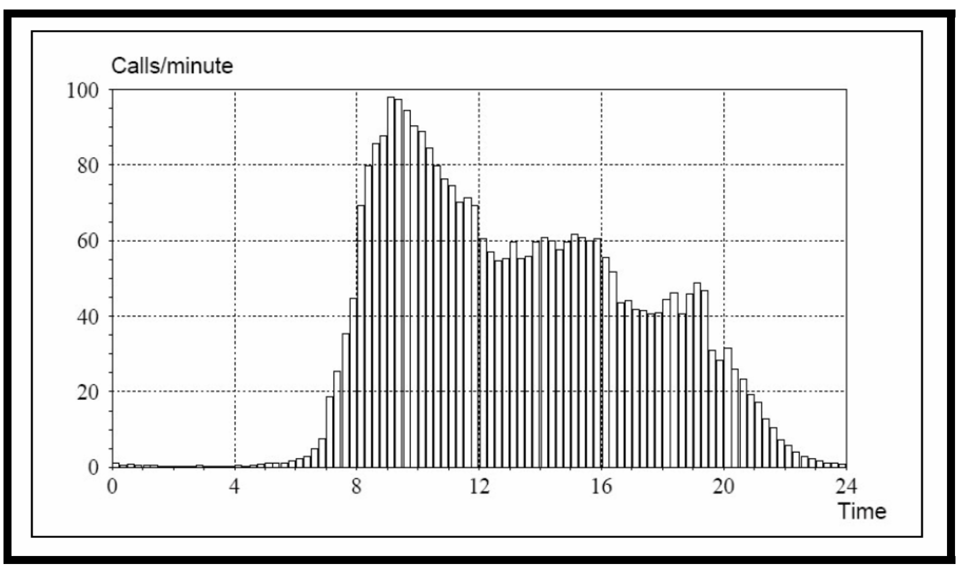

Figure 3.11. A typical traffic profile for a 24 hour period (from [3]).

Analyzing the traffic curve in Figure 3.11 [3] one can see that the first peak is during the morning hours (business subscribers). Right before noon it seems to drop off a bit for the lunch hour and begins to taper off at 1600 with expected spikes in the evening (private calls and rate reductions).

This now leads to the basis of network planning – traffic prediction between exchange nodes. It is here where a new tool is introduced which is used by PLANITU; the traffic matrix (see Figure 3.12 [3]). The traffic matrix consists of exchange nodes (rows and columns) and Erlang values (populated data). An Erlang is simply a measure of the number of busy resources at a given instant in time or alternatively a unit that represents the amount of traffic a one hour phone call would produce.

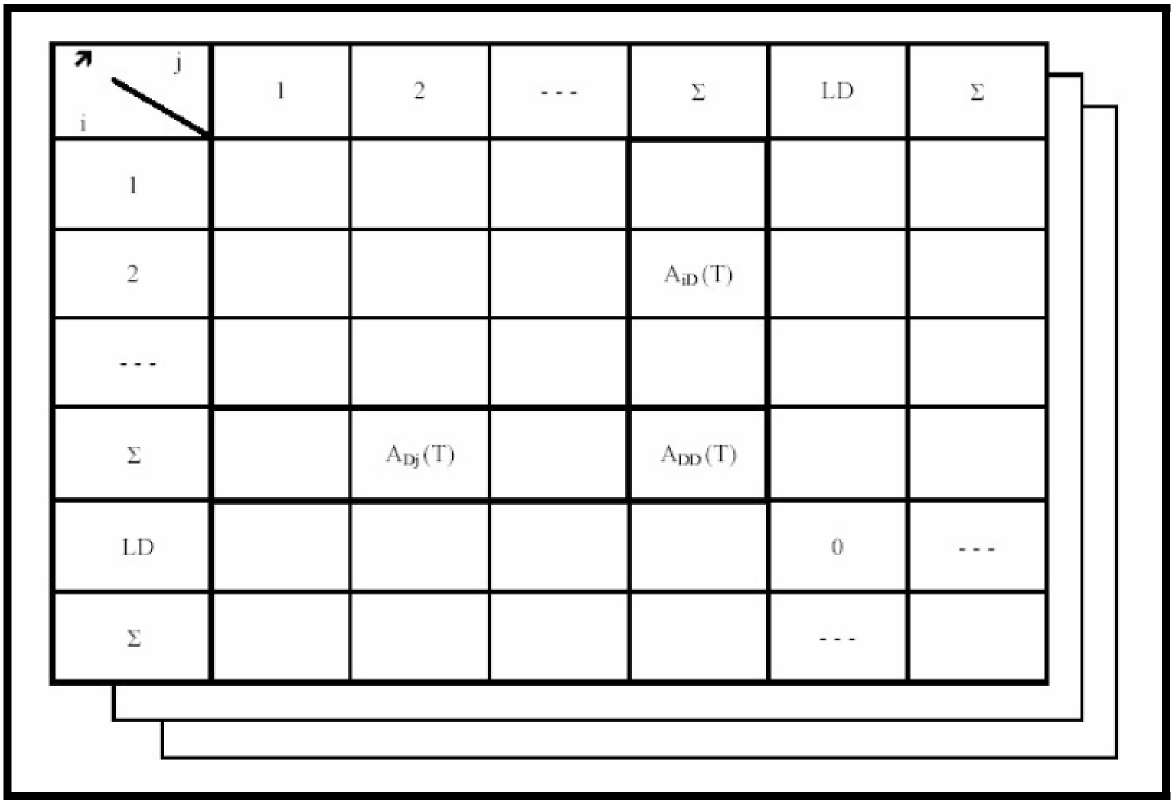

Figure 3.12. An illustration of a set of traffic matrices consisting of one traffic matrix for each service (from [3]).

PLANITU does not actually try and predict a traffic matrix, it simply uses either a measured matrix provided by a network operator or a separate tool to predict a matrix. There are two separate tools used for matrix prediction, FcMetro and FcRural which are bundled with PLANITU 3.0 [1]. Each program is used for the specified type of network. In order to predict a matrix, carefully measured and statistically generated data is needed, such as the number of subscribers connected and waiting (far-future demand), traffic weight factor between traffic areas, subscriber categories, traffic per subscriber line per category (calling rate), separate forecasts of long distance and mobile calling rates, and

traffic dispersion factors between subscriber categories [1]. Once this data is collected, formatted and crunched one could expect to see a traffic matrix like in Figure 3.13 [1]. More details about these programs and how they work will be covered in chapters IV and V.

Traffic matrix between TA:

	ARO	WKO	PRK	NGL	GBG	RKT	BPG	SDA	SDS	BKL	SDY	DDS	SPS	LD
ARO	79.40	521.02	213.09	406.49	152.40	166.60	45.59	1027.93	48.40	203.48	38.81	14.60	29.47	440.47
WKO	185.08	1114.40	719.52	1408.03	596.56	483.55	191.69	2349.76	187.19	816.99	162.45	61.80	83.61	885.87
PRK	152.78	644.27	436.75	922.14	337.52	356.83	123.98	1427.20	108.92	442.16	87.85	34.07	51.26	640.34
NGL	248.03	1285.87	753.10	1459.03	989.12	731.00	223.87	2508.15	173.28	798.74	226.95	86.72	95.80	1094.47
GBG	71.17	402.56	215.55	481.74	261.32	252.41	85.79	835.44	59.32	254.87	72.59	28.16	30.51	328.84
RKT	170.04	631.32	362.55	778.70	332.61	349.89	143.09	1400.43	82.77	437.40	86.91	41.16	48.66	566.83
BPG	19.59	132.11	66.57	154.25	73.63	66.86	35.20	259.33	16.13	107.32	21.36	9.77	9.72	59.63
SDA	633.62	2451.52	1393.08	3014.24	1305.76	1351.89	568.72	5405.39	321.84	1738.37	345.47	162.61	188.81	2073.76
SDS	45.97	171.60	98.51	212.26	91.59	95.57	39.62	383.64	22.84	121.17	24.08	11.33	13.32	151.21
BKL	70.73	468.23	236.71	547.59	260.93	237.63	124.48	922.79	57.37	379.63	75.55	34.58	34.51	197.12
SDY	16.73	111.78	56.42	130.64	62.32	56.67	29.76	219.95	13.68	90.76	18.06	8.27	8.23	48.29
DDS	10.93	60.30	31.52	71.39	32.97	31.24	15.33	122.13	7.47	46.78	9.31	4.30	4.48	34.23
LD	510.06	996.13	740.57	1276.09	381.12	649.86	50.59	2314.40	165.34	183.48	43.09	34.89	0.00	0.00

Figure 3.13. A traffic matrix of 14×13 for year 2008 generated by FcMetro. Labels such as ARO (Asemrowo) and WKO (Wonokroma) represent traffic area names (from [1]).

D. CHAPTER SUMMARY

In this chapter, three different types of switched network systems were covered: metropolitan, rural area and GSM. Also covered were introductions to traffic profiles and the concept of traffic matrices. Chapter IV will go into more depth to discuss the Erlang-B loss formula and the Wilkinson ERT method; two concepts used heavily in the iterative processes. Chapter IV will also discuss a matrix estimation technique used by PLANITU. Finally, the concept of “Grade of Service” will be introduced to include how it is used in regards to network engineering and its importance to network planning.

IV. TRAFFIC ENGINEERING AND ESTIMATION

In this chapter, the Erlang-B loss formula will be discussed along with the Wilkinson ERT method; two equations that PLANITU uses in the iterative process for traffic blocking calculations. Additionally a traffic matrix estimation technique used by a program external to PLANITU will be discussed; the concept of Grade of Service (GoS) and how it is used will also be covered.

A. ERLANG-B LOSS FORMULA AND WILKINSON'S ERT METHOD

Before simulation data can be explored, a deeper understanding of traffic engineering basics must be introduced. In telecommunications networks, an import requirement is to determine the number of voice circuits needed for a given call traffic demand while at the same time maintaining a certain GoS (blocking probability threshold). A Danish Mathematician named A. K. Erlang developed such a technique over a hundred years ago [6]. For the purposes of traffic engineering and estimation, the demand is often referred to as offered traffic or offered load, and is given the dimensionless unit Erlang, as stated in the previous chapter. An Erlang is the amount of traffic a one hour phone call would generate. Offered traffic in Erlangs can be best characterized by the following product:

Offered traffic (ρ_1) = Average call arrival rate * average call duration time

Thus, for C circuits, the call blocking probability is given by the following Erlang-B loss formula:

$$E_B(\rho_1, C) = (\rho_1{}^C / C!) / (\sum_k^C (\rho_1{}^k / k!)) \tag{0.1}$$

Where the summation is from k=0 to C. It should also be noted that this formula is developed under the assumption that the arrival traffic follows a Poisson process, while the results being insensitive to the actual statistical distribution of the call duration time [3].

As stated earlier it is important to know the number of circuits that will be required for a given traffic load and GoS. PLANITU uses a simple iterative method using Equation (4.1) to determine the number of required circuits for a given load. A simple

example of this would be to assume a grade of service of 1% which is a typical value considering most telecommunication and cellular providers promise between one and five percent [4]. Thus, for 100 Erlangs of offered traffic and a 0.01 call blocking probability, using Equation (4.1) iteratively one can conclude that 117 circuits are needed. A good online Erlang calculator to try this out on can be found at [7].

In most cases telecommunications operators are only interested in the busy hours of the day and its impact on network performance as discussed in chapter III. In most cases, the average Erlang offered traffic per customer can be determined from operational measurements. A more practical example can be seen if the average offered traffic per customer is 0.03 Erlang which is about a two minute call, then for an offered traffic of 100 Erlang, the average number of customers that can be supported with 117 circuits is little over 3,300 customers. Since the population size is very large, the Erlang-B loss formula still turns out to be a very good approximation [3].

In reality, the offered traffic is hard to estimate. Only measured traffic, or carried load can be determined. What is interesting is that it can be shown that the carried traffic is nothing but the average number of busy circuits [3]. Thus, for a measured carried load $\rho_1^{'}$ and given the number of circuits, C, we have the following relation [3]:

$$\rho_1^{'} = \rho_1(1 - E_B(\rho_1, C)) \tag{0.2}$$

The above equation is used by PLANITU to iteratively solve for the offered traffic ρ_1. It is clear that the advantage of the Erlang-B loss formula is that it gives a relation between offered traffic, call blocking, and the number of circuits.

PLANITU uses another technique for traffic engineering; the Equivalent Random Theory (ERT) method, also known as the Wilkinson method [3]. For example consider Figure 4.1 [8]. Figure 4.1 is a basic system where C + S are trunks (access points) which are being accessed by two classes of calls, which offered loads ρ_1 and ρ_2 Erlangs. The class one calls first searches the C trunk; if they are all busy; these calls then search the S trunks. The class two calls are only allowed to search the S trunks. If calls from either class do not find a vacant trunk they are blocked and do not receive service.

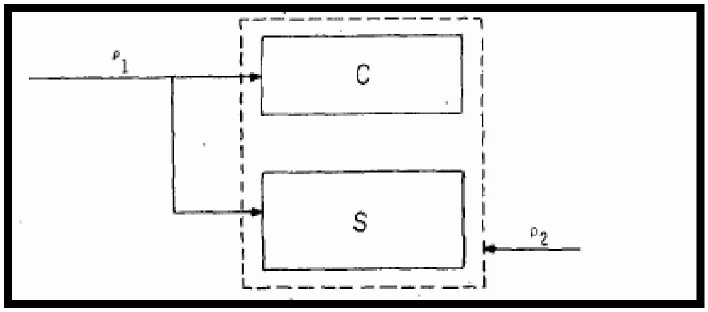

Figure 4.1. A basic trunk group configuration (from [8]).

To apply the Wilkinson's ERT method to Figure 4.1 [8] first the mean (α) and variance (ν) of the overflow process from C must be computed using equation (4.3) and (4.4).

$$\alpha = \rho_1 E_B(\rho_1, C) \tag{0.3}$$

$$\nu = \alpha(1-\alpha+\rho_1/(C+1+\alpha-\rho_1)) \tag{0.4}$$

Now the same must be computed for S trunks where (β) is the mean and (ν_2) is the variance. See equations below.

$$\beta = \alpha + \rho_2 \tag{0.5}$$

$$\nu_2 = \nu + \rho_2 \tag{0.6}$$

Next we define a peak factor called z, which is given below.

$$z = \nu_2 / \beta \tag{0.7}$$

With the collected data above, the behavior on the S trunks can be analyzed by using the Wilkinson's ERT [8]. First an equivalent random load, A, must be computed. This value is to be offered to M trunks and then overflowed to the S trunks, such that the mean and variance of this overflow process is equal to β and ν_2 as shown below.

$$A = \nu_2 + 3z(z-1) \tag{0.8}$$

$$M = [A(\beta+z)/(\beta+z-1)] - \beta - 1 \tag{0.9}$$

At this point it's obvious that M may not be an integer value so we designate a new value.

$$N = \lfloor M \rfloor \tag{0.10}$$

N is now the largest integer less than or equal to M. Now the blocking on the M trunks can be computed from Equation (4.11) where PBB represents the blocking probability on M trunks.

$$PBB = E_B(A,N)(A/(N+1+AE_B(A,N)))^{(M-N)} \tag{0.11}$$

The next step is to find the blocking on the composite number S+M trunks. Once again this value may not be an integer so it is designated $N_2 = [M+S]$. This represents the greatest integer less than or equal to $M+S$, next the composite blocking on the $M+S$ trunks can be calculated by using equation (4.12).

$$PBB_1 = E_B(A,N_2)(A/(N_2+1+AE_B(A,N_2)))^{(M-N)} \tag{0.12}$$

The final step in the Wilkinson's ERT method is to compute the total loss probability on the S trunks, PL, by using equation (4.13).

$$PL = PBB_1 / PBB \tag{0.13}$$

To summarize this method; the technique assumes a number of traffic streams, characterized by their individual mean and variance, which are then offered to a common Erlang loss system consisting of a number of channels [8]. The total mean and variance of the traffic system is defined as the sum of the individual means and variances. It is assumed that the total overflow of this system can be represented by an equivalent Poisson flow arriving to an equivalent system consisting of a number of channels. It is these values for the equivalent flow and equivalent system which PLANITU calculates. The overall blocking is then approximated for the equivalent system by using the Erlang-B Equation (4.1) for the entire system. PLANITU determines the individual blocking probabilities of each traffic stream by using parcel blocking probability techniques [1]. The next section will give an introduction to traffic matrix estimation which is used by FcMetro and FcRural.

B. TRAFFIC MATRIX ESTIMATION TECHNIQUES

In chapter III the concept of a traffic matrix was introduced. To review; a traffic matrix reflects the volume of traffic that flows between all possible pairs of sources and

destinations in a switched circuit network in units of Erlangs. The information that a traffic matrix contains is extremely important in the process of network engineering. An accurate traffic matrix allows the network engineer to predict and compute load balancing, configure a routing protocol, dimensioning, provisioning and failover strategies [9]. This kind of capability is critical for proper network planning and diagnosing. PLANITU does not actually estimate a traffic matrix; an external program called FcMetro or FcRural accomplishes this. PLANITU takes the matrix file as input and uses the values for all calculations.

It is well known that populating a traffic matrix with measured data is expensive. There are better ways of gathering traffic matrix data than measurements [9]. There exists estimation techniques based on partial information. This section will give a brief introduction to one of these techniques which is used by FcMetro and FcRural for all matrix estimations.

FcMetro and FcRural use a statistical approach. Figure 4.2 [9] shows a diagram of the generalized approach.

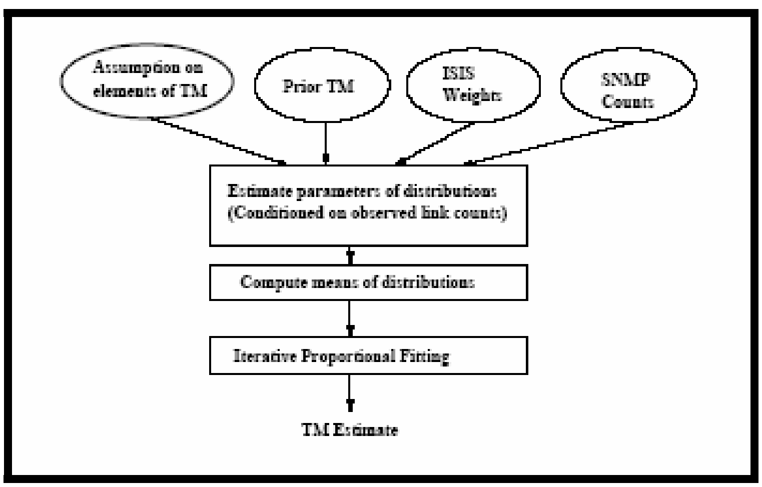

Figure 4.2. A generalized diagram for a statistical approach (from [9]).

Above we see that there are four general inputs to the statistical approach. All statistical methods need a prior traffic matrix to get started. Usually these prior matrices can be put together based on statistical data about the local population density, growth rate, subscription demand and area coverage [1]. The ISIS weights are used to compute the shortest paths which in turn generate the traffic matrix. The final input from Figure

4.2 is the SNMP data, which gives the observed links counts. All these inputs are used to develop constraints on the traffic matrix estimation [9].

Given all the inputs, the first step is to estimate all the parameters of the distributions assumed for the traffic matrix. Other parameters are estimated if needed for a given model. The next step is to compute the conditional mean value for the distribution associated with each component of the traffic matrix. After this process a final adjustment is applied to the result from the previous step which is an iterative proportional fitting algorithm [9]. This algorithm then proceeds to adjust the values of the estimated traffic matrix such that the error with respect to the row and column sums is minimized. This is the process that FcMetro and FcRural use for traffic matrix prediction [1]. The difference between the two lies in the iterative proportional fitting algorithm. The input files for the prospective programs will be discussed in further detail in Chapter V and simulation results will be examined in Chapter VI.

There are of course other approaches for matrix prediction. Such methods include linear programming, the Bayesian approach, and expectation maximization [9] to name a few. Some techniques do not require a previous matrix. One such example is the expectation maximization, also known as EM process. Further details of these techniques are beyond the scope of this paper.

Now that traffic engineering and matrix estimation has been covered it's important to discuss a concept which has been talked about previously – Grade of Service.

C. GRADE OF SERVICE

Earlier in this chapter the term of GoS was used for Erlang calculations. GoS is defined as a number of traffic engineering parameters to provide a measure of adequacy of network operation under specified conditions [10]. GoS parameters are expressed as a probability of blocking delay distribution. This value was usually given as a percent value typically ranging from one to five percent, which are common values promised by many service providers [4]. Another important concept which is part of GoS is Quality of Service (QoS). A common mistake made is the use of QoS and GoS interchangeably. The difference between the two is that QoS is merely an objective within grade of service see Figure 4.3 [10]. Put in its simpler terms QoS supports levels in terms of delay, jitter,

call loss, reliability, and availability [3]. These values will be pre-defined within requirements when designing a network system [10].

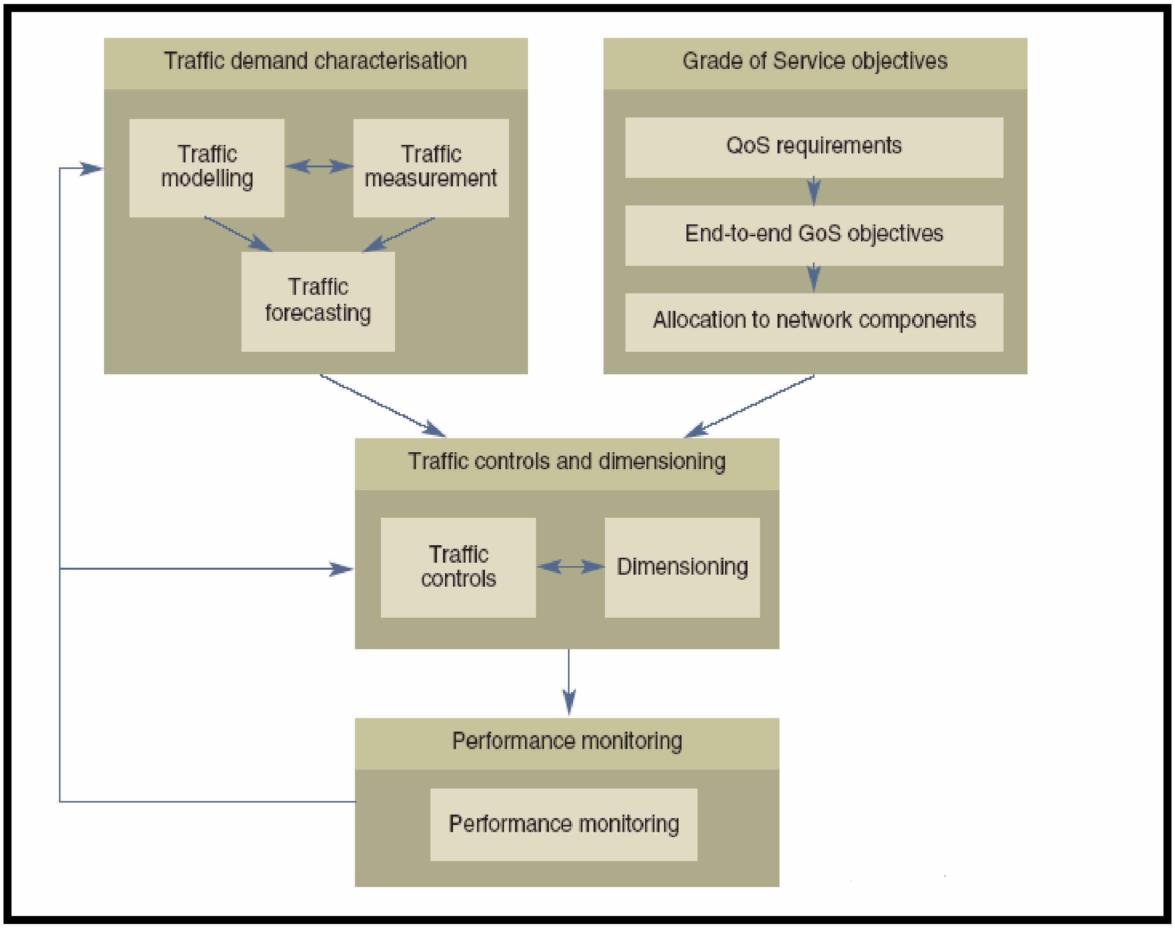

Figure 4.3. The tasks involved in traffic engineering, as seen from ITU-D (from [10])

It is now helpful to define Network Performance (NP) in terms of network planning. NP is defined as the ability of a network or network portion to provide the functions related to communications between users [10]. GoS is the traffic related part of NP.

To better define how all three of these terms are related, NP and GoS objectives are derived from QoS requirements (see Figure 4.3). Basically, QoS should be user-oriented and, in principle, independent of the network. It should be noted that NP parameters are network-oriented, put in simpler terms they can be used when specifying performance requirements.

Now that the GoS and QoS are fully defined its time to move on to the simulation environment of PLANITU. The next chapter will discuss model specifics such as data requirements, input data files and network specific files for the Thailand National Network and a GSM network model.

D. CHAPTER SUMMARY

In this chapter, the Erlang-B loss formula and the Wilkinson ERT method were discussed in detail. PLANITU uses these formulas heavily in the prediction of call drops and network performance estimation. Next discussed was the traffic matrix estimation technique used by the accompanying software to PLANITU, FcMetro and FcRural. These programs use a purely statistical approach in their iterative process. Other techniques of traffic prediction were mentioned. This chapter concluded with a definition of GoS and how it differs from QoS and also introduced network performance and how all three are related in traffic engineering.

V. SIMULATION ENVIRONMENT

In this chapter, the system requirements and simulation environment will be discussed in detail for three examples. The first example will include a description of the required input data files for FcMetro and expected output files proper format and structure of each file in order to obtain a simulated traffic matrix. Next, a model description of the Thailand national network will be discussed all input data files, and finally a GSM network using real data will be described listing all input files needed; all actual data files are listed in Appendices A, B, and C.

A. SYSTEM REQUIREMENTS

Since PLANITU and FcMetro were last updated in June 2002 the computer system requirements are not very demanding. All simulations for this paper were conducted on a basic Pentium 4 note book with a CPU rated at 1.8 GHz and 512 Mbytes of RAM running on a Windows XP operating system. Of course these values are much more than are required. Minimum requirements for PLANITU 3.0 and FcMetro are listed below [1]:

- PC running Windows 9x, NT, 2000, Me, XP operating system.
- 128 Mbytes of RAM.
- 20 GBytes hard disk.
- SVGA graphics card with min 17 inch monitor.
- CD ROM for software installation.
- LAN card.

Also needed, but not essential is a digitizer and scanner. A digitizer can make life much easier when it comes to complex network topologies especially for large metropolitan networks. The digitizer can turn CAD drawings of networks into two dimensional coordinates which can easily be read into input data files. The scanner can be used to add raster maps under-laid in the PLANITU graphics. The purpose of adding raster maps is to further enhance network details for the network planner, such as adding geographical information such as buildings, trees, roads, mountains, rivers and lakes.

B. MODEL DESCRIPTION FCMETRO

As discussed in chapter IV, FcMetro and FcRural are the programs responsible for calculating a traffic matrix which could be used by PLANITU for network simulations. The FcMetro forecasting program uses separately forecasted traffic including variables and subscriber demand forecasts to automatically calculate an offered point-to-point traffic matrix between exchanged nodes [1].

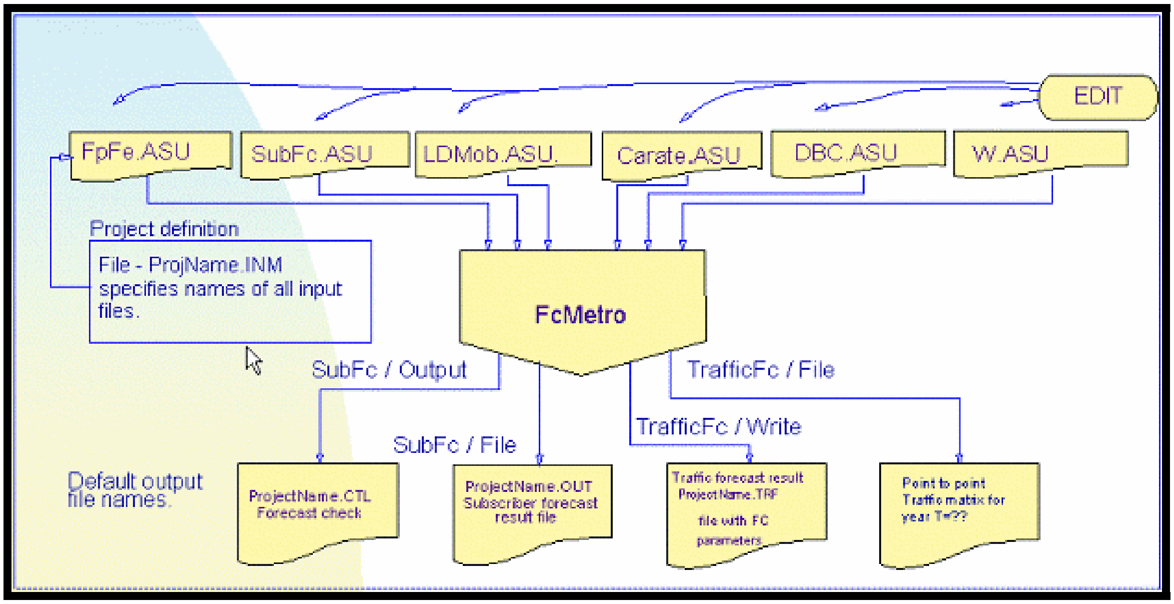

Figure 5.1. Functional block diagram showing FcMetro data processing and results generated (from [1]).

Above in Figure 5.1 we see that there are six input files. These files are predefined and all that is needed is to change the values for your specific example FpFe.ASU, SubFc.ASU, LDMob.ASU, Carate.ASU, DBC.ASU and W.ASU. ".ASU" is the extension that FcMetro attaches to all input files for recognition purposes. Below we see a summary of each input file. Appendix A contains all the actual data files in proper format.

- **FpFe.ASU** - This file describes the shape and growth curves with correction factors represented with population factor (FP), employee factor (FE), and coin box factor (FC), better known as pay phones. These are defined for each traffic area and for distinct points of time, for example T=0, +5, +10, +15 years ahead [1]. For this particular file the population correction factor, FP,

affects the forecast of residential lines, while FE and FC factors affect business line forecast.

- **SubFc.ASU** – This file contains the connected and waiting subscribers and far-future forecasted demand on the planning horizon [1].
- **LDMob.ASU** – This file contains data for separate forecasts of long distance and mobile calling rate [1]. Long distance calling rates are forecasted separately and are also inserted into this file.
- **Carate.ASU** – This file contains data for traffic per subscriber line per category. In other words the proper calling rate forecast per traffic area and subscriber category [1].
- **DBC.ASU** – This file contains traffic dispersion factors between subscriber categories [1]. These values are crucial for traffic forecasting purposes.
- **W.ASU** – This file contains traffic weight factor between categories and traffic areas [1].

Having prepared all the above input files, the FcMetro forecasting program will calculate subscriber demand for each planning zone and traffic between traffic areas for each point in time (traffic matrix). This traffic matrix can then be imported into PLANITU for network modeling and simulation. FcMetro will generate two output files SubFc/Output (ProjectName.CTL) – which contains the complete subscriber forecast results including the traffic matrix – and TrafficFc/Write (ProjectName.TRF) for just the traffic matrix. The actual point to point traffic matrix will have the .TRF extension. Also included in output will be each file in ASCII format ready for plug and play into PLANITU data files. The results of this simulation will be discussed in chapter VI. The next section will cover building the Thailand National network system from real data collect in 1995 by Siemens Indonesia [2].

C. MODEL DESCRIPTION FIXED THAILAND NATIONAL NETWORK

To build a complete fixed network system in PLANITU requires three kinds of data [1]:

- “Relatively fixed data”, like cost data, service standards, basic zones, traffic areas, and nodes.

- "Network data", like locations, boundaries, exchanges, remote subscriber units (RSU), routing information.
- "Forecast data", subscriber and traffic matrices (FcMetro or FcRural).

PLANITU requires eleven different files. Below is a list of all required input files with a short description of each. Appendix B contains all the actual data files in proper format.

- **Build.tha** – Data file containing costs of buildings extensions, as well as parameters for subscribers/circuits to surface conversion [1].
- **Cosw.tha –** Marginal switch cost file. This cost consists of switching costs in the originating and terminating exchanges and a transmission cost that is dependent on chosen transmission media and the distance [1].
- **Excost.tha –** Switching cost table file. This file contains the list of switching equipment, including RSUs [1].
- **Exdefd.tha –** Reference definition file. This file references to a type of host exchange, used to define RSU's [1].
- **Gos.tha –** Contains GoS or Grade of Service [1].
- **Links.tha –** File which contains block definition of links [1].
- **Newexd.tha** – File containing parameters for adding new exchanges such as detailed information about the switching equipment [1].
- **Nodes95.tha** – An ASCII file containing coordinates and additional information of all exchange nodes [1].
- **Rout.tha –** File which contains the type of routing protocol or routing plan used [1].
- **Traf95.tha –** Measured traffic matrix [1].
- **Transys.tha –** File containing information about the transmission system [1].

This completes the required input files for the Thailand fixed network system. Chapter VI will cover the simulation results and analysis.

D. MODEL DESCRIPTION GSM NETWORK

A new feature added on this release of PLANITU is the GSM capability. The GSM model also requires eleven different data files. All input files contain the same type of information as the Thailand network in the same format. Comparing the input files,

seven out of the eleven are exactly identical to the Thailand network; Build, Cosw, Excost, Gos, Newexd, Rout and Transys (see Appendix C.) The files that are different are Exdef, Links, Nodes and Traf. Taking a closer look at these files, the differences that separate the Thailand fixed and the GSM is the optimization rule. The GSM specifies a optimization rule of optimal location while the fixed state fixed optimization rules. The other difference between the models is under the Link file in the definitions table. The distance is much higher for the fixed, which is what one would expect considering the area that the Thailand network covers. Other than these two differences there is absolutely no difference in models. Chapter VI will cover the results of this simulation.

E. CHAPTER SUMMARY

In this chapter, the system requirements and simulation environment were covered. This consisted of describing all input data files for FcMetro traffic matrix estimator, PLANITU data files for the Thailand National network and an implementation of a GSM network. All input files were derived from real data collected in 1995 by Siemens Indonesia [2]. Appendices A, B and C contain all actual input data files in the proper format. Chapter VI will cover the detailed simulation results and analysis.

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VI. SIMULATED RESULTS AND ANALYSIS

In this chapter, the results for FcMetro traffic matrix program, the Thailand National network and the GSM model simulation results and analysis of the results will be covered. Also included for each network model will be examples of PLANITU program capabilities, such as network response to congestion, link failure, route failure and exchange node failure. Other capabilities, such as optimal exchange node placement, will also be covered.

A. FCMETRO SIMULATION RESULTS

Once all the required input files have been input it is a simple matter of running the program. The first area to explore is the subscriber forecast for all zones. Below in Figure 6.1 is the subscriber forecast predicted for four year intervals generated by FcMetro.

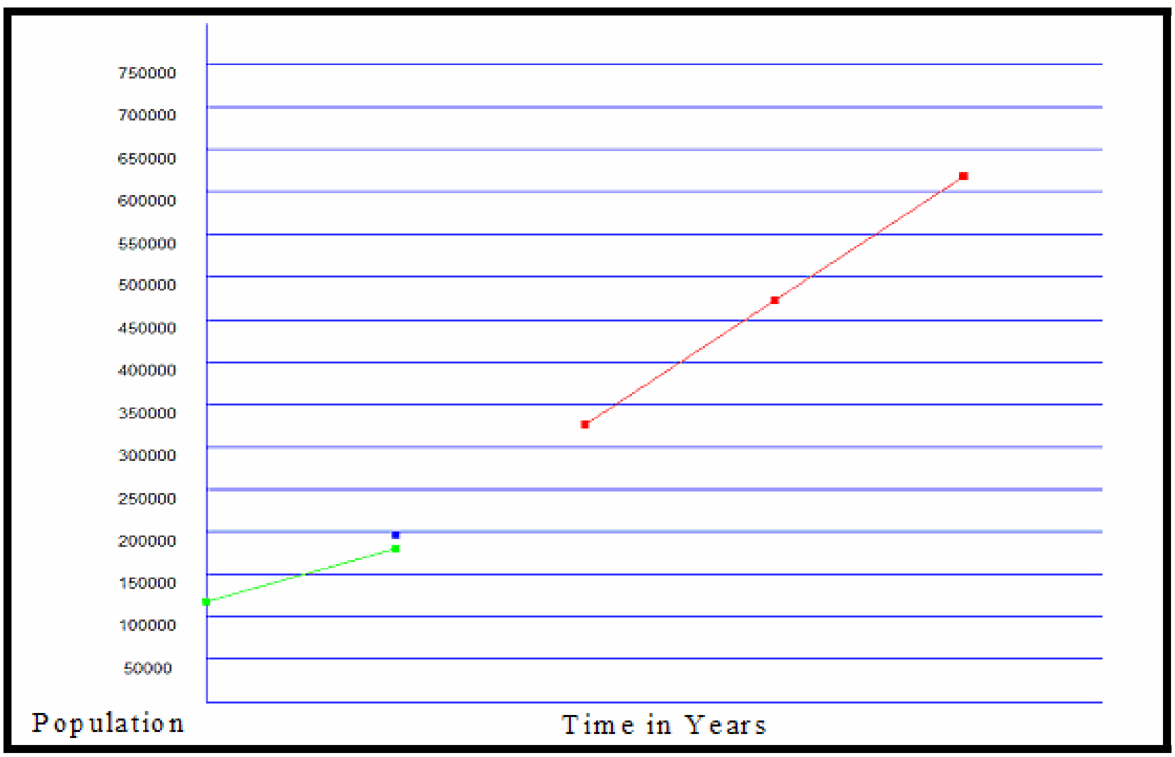

Figure 6.1. A subscriber forecast for all zones. The y-axis represents the population and the x-axis is the time axis. Each plotted point represents a distinct point of time, (e.g. four year intervals.)

Next FcMetro has the capability to forecast for each individual traffic area. For our input data four traffic areas were input CEN, TRI, FND and MRA. For this example CEN was selected see Figure 6.2. Once again CEN was plotted for every four years. FcMetro gives option to plot for every area specified in the input data files.

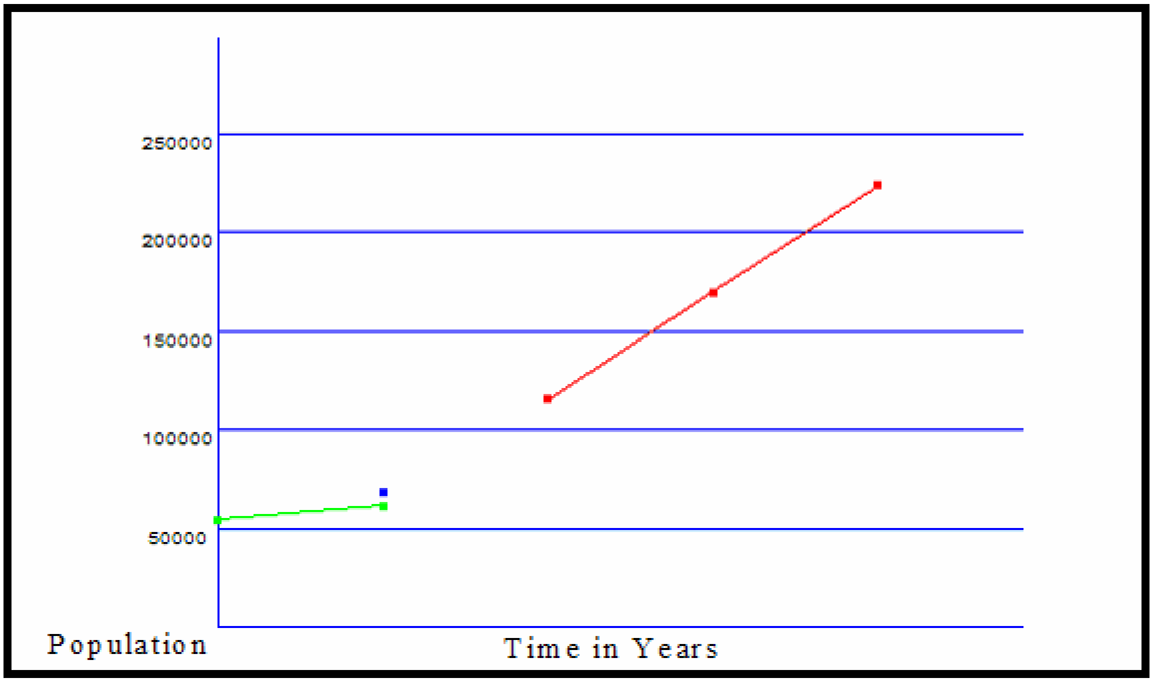

Figure 6.2. Area subscriber forecast for the entire CEN zone. The y-axis represents the population and the x-axis is the time axis. Each plotted point represents a distinct point of time (e.g. four year intervals.)

Next is the generation of the traffic matrix. FcMetro allows you to choose which year in time you wish to see the predicted traffic matrix. For this example the year 1998 was chosen. Below in Figure 6.3 is the generated matrix. Each number has units of Erlangs, and is in proper PLANITU input form.

```
  7 Traffic matrix for year  0 (1998)
Format:(10F8.1)
  2942.9  1717.3  1124.8   939.8  2241.6   907.7   907.7
  1740.6  1015.7   665.3   555.8  1325.8   525.5   525.5
  1053.8   614.9   402.8   336.5   802.6   498.6   498.6
   720.4   420.4   275.3   230.0   548.7   218.3   218.3
     0.0     0.0     0.0     0.0     0.0     0.0     0.0
   776.4   411.5   468.2   253.0     0.0     0.0     0.0
   776.4   411.5   468.2   253.0     0.0     0.0     0.0
```

Figure 6.3. A generated traffic matrix for 1998. All values are represented in Erlangs with columns and rows representing exchange nodes.

Now that we have seen the results produced by FcMetro, it should be noted that the matrix above is merely a prediction based on statistical iterative algorithms such as discussed in chapter IV. The accuracy of the matrix is only as accurate as the input data collected. Extreme care should be taken in the collection of such data in order to yield as accurate a matrix as possible. The next section will use a measured traffic matrix as input data for the Thailand National network [1].

B. THAILAND NATIONAL NETWORK RESULTS AND ANALYSIS

In this section PLANITUs optimization results and network sensitivity capabilities for a real network system simulation will be covered.

The first step after reading in all the input files would be to get a graphical representation of the Thailand national network. In Figure 6.4 is a geographical map of Thailand provided by [11] in Figure 6.5 is the exchange nodes plotted out with PLANITU graphics with each node labeled.

Figure 6.4. A map of Thailand displaying all major cities and surrounding countries (from [11]).

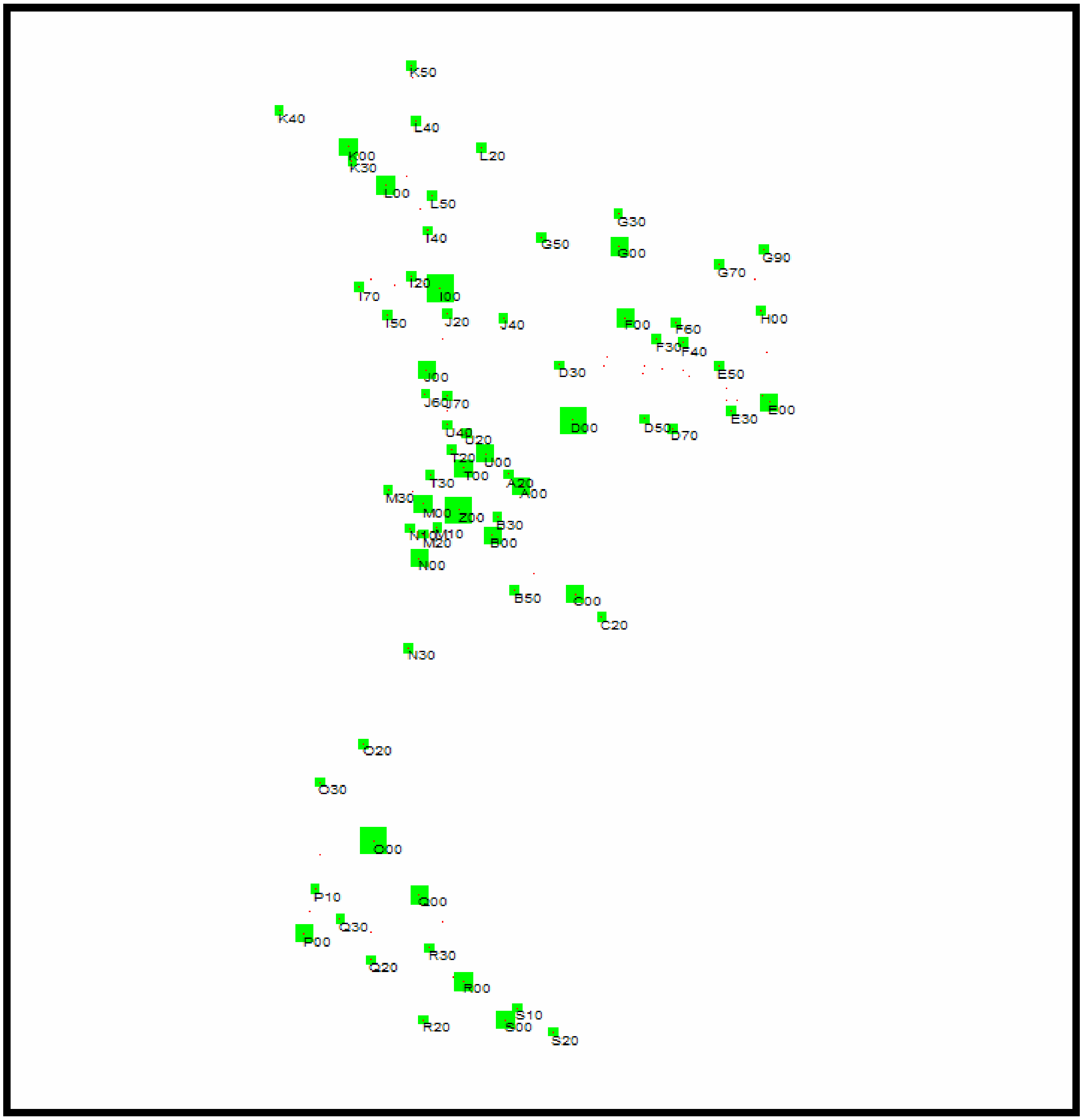

Figure 6.5. A graphical representation of the Thailand network plotted out by PLANITU with all exchange nodes labeled.

From Figure 6.5 it is observed that each exchange node is located in a major city location within the country. The larger the square, the larger the concentration of population. It would now be helpful to see the transmission links, or runs, within the network as described in the input data files (see Figure 6.6.)

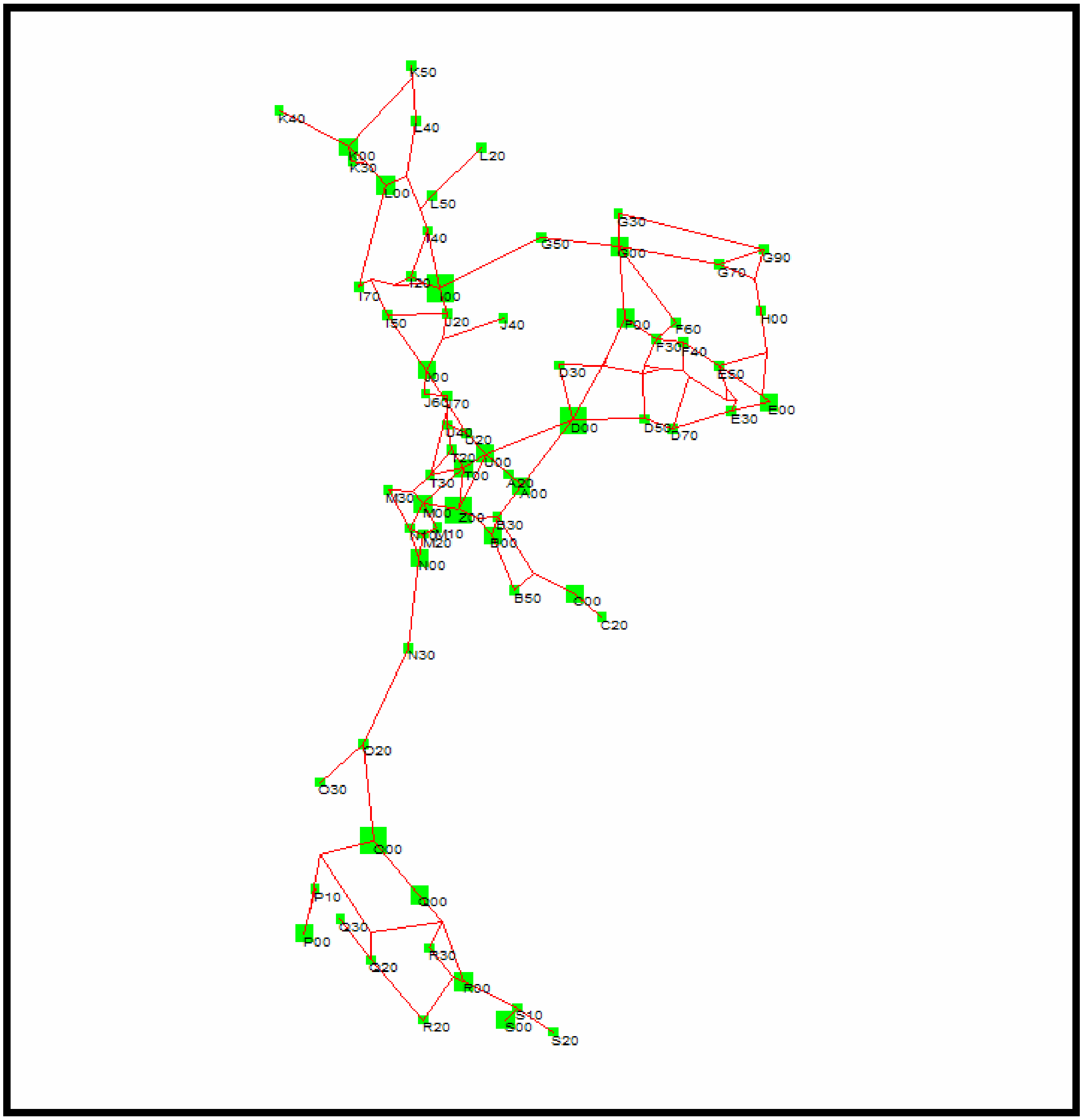

Figure 6.6. A graphical representation of the Thailand network high traffic links or runs.

The above figure shows the links of highest rate of flow of traffic or highest usage for the network [1]. It would also be helpful for the network planner to see a hierarchy of the network. PLANITU has a hierarchy feature where a graphical representation can be seen (see Figure 6.7.) Once again a red link is for high usage and blue is for below normal usage.

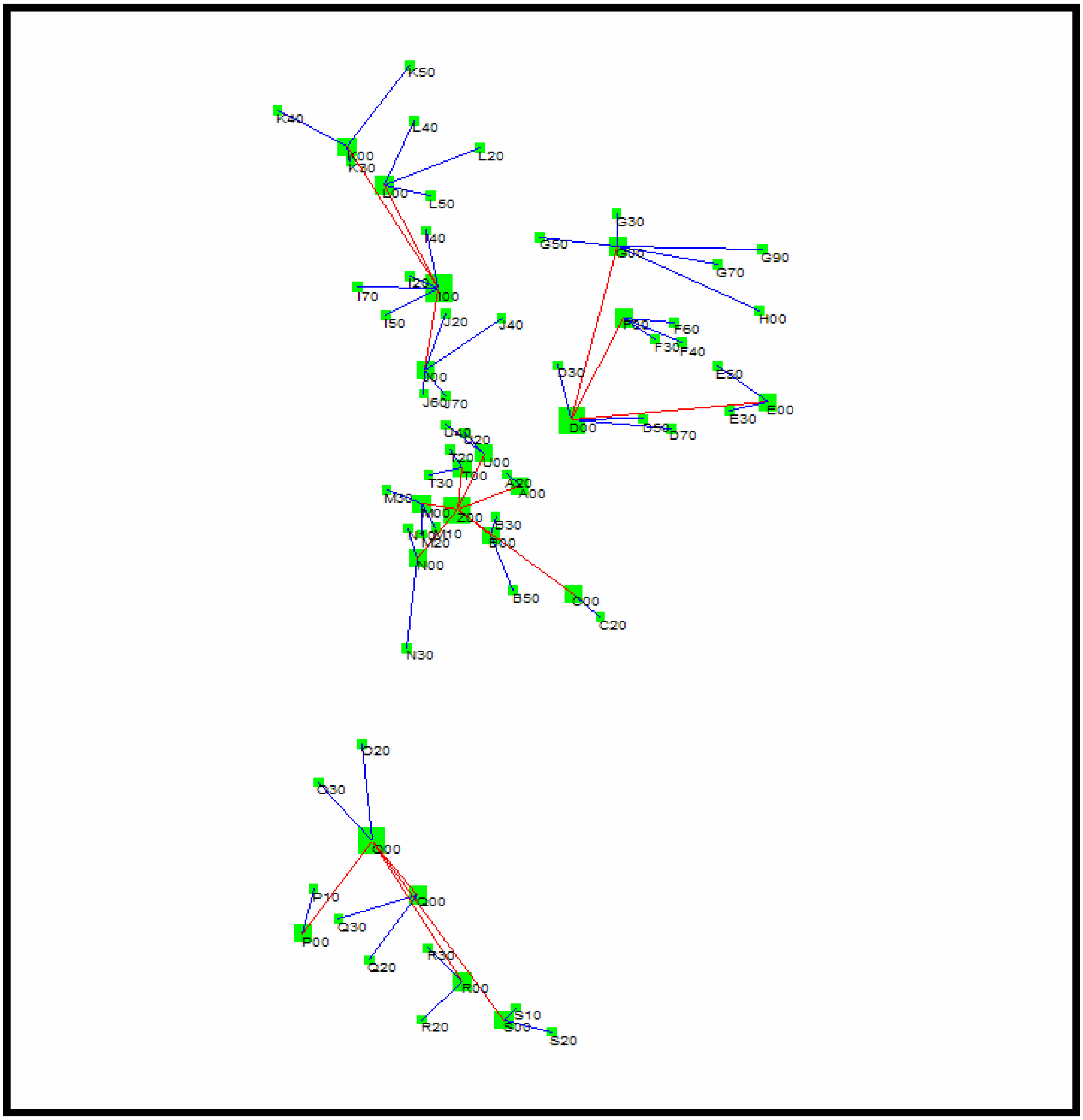

Figure 6.7. A graphical representation of the hierarch of the Thailand network. The representation also shows how the districts in the network are isolated.

Now its time to demonstrate something useful, such as using PLANITU to choose the best route to connect exchange nodes for the least cost path. PLANITU can calculate this for three different criteria; least cost, shortest distance, and most reliable. In the next figure the least cost route was graphically displayed for connecting exchange node K50 to S20 (see Figure 6.8.)

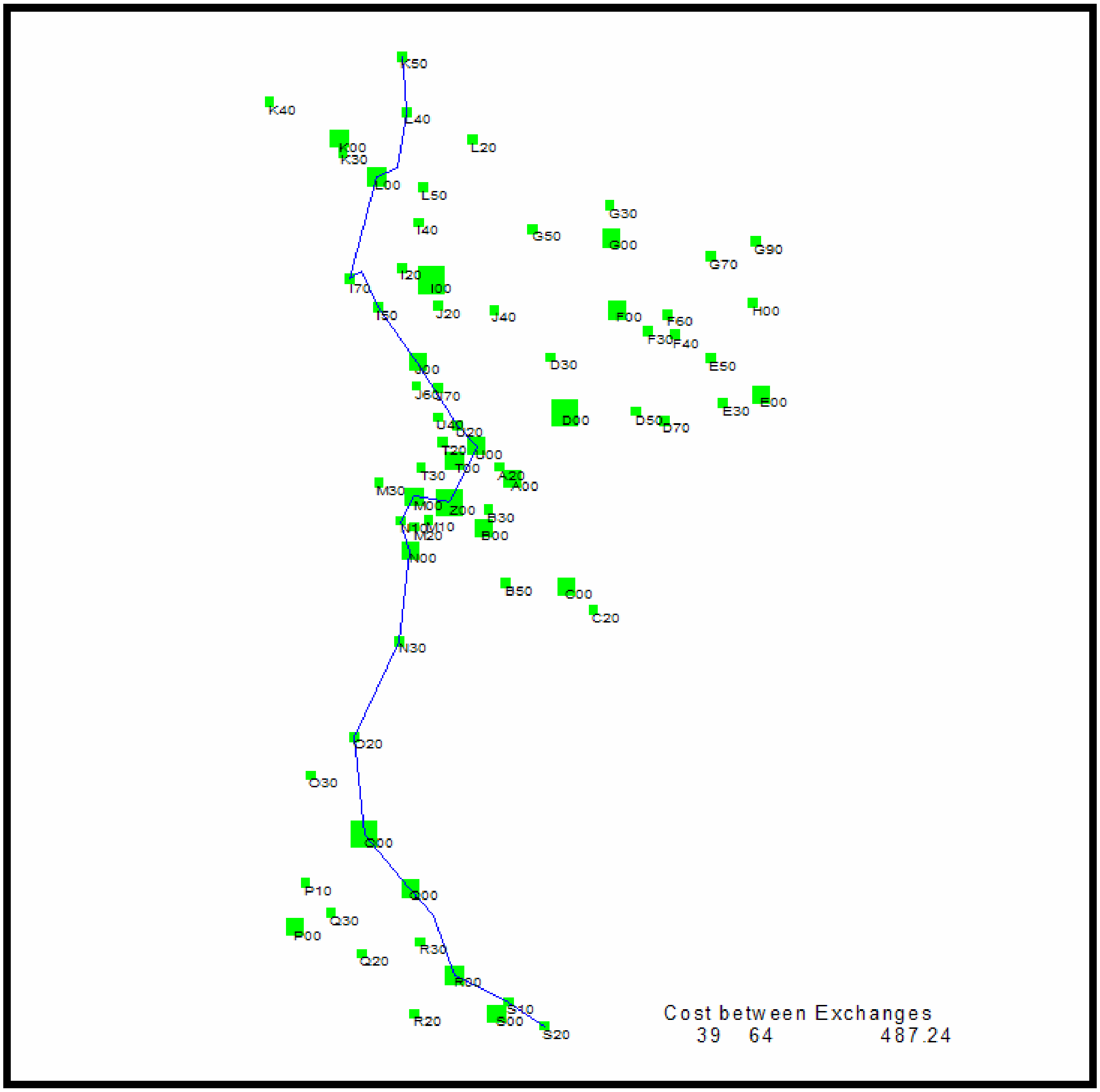

Figure 6.8. A graphical representation of a least cost route calculation between exchange nodes K50 to node S20.

Figure 6.8 shows connections 39 and 64 have a cost of 487.24. The notation 39 and 64 can be misleading. 39 is the number entry associated with the K50 node and 64 is associated with S20. This represents the line number from which the nodes were entered into the Nodes.tha file. PLANITU also displayed a cost value of 487.24 as the cost for the connection. The 487.24 has a unit of MU or monetary unit. Back in 2002, 10 US dollars would equal one MU [1]. Of course by today's standards this value would be a little more due to inflation. This value can be updated to reflect today's inflation in the

Cosw.tha file [1]. Now it would be helpful to demonstrate the optimization portion of PLANITU.

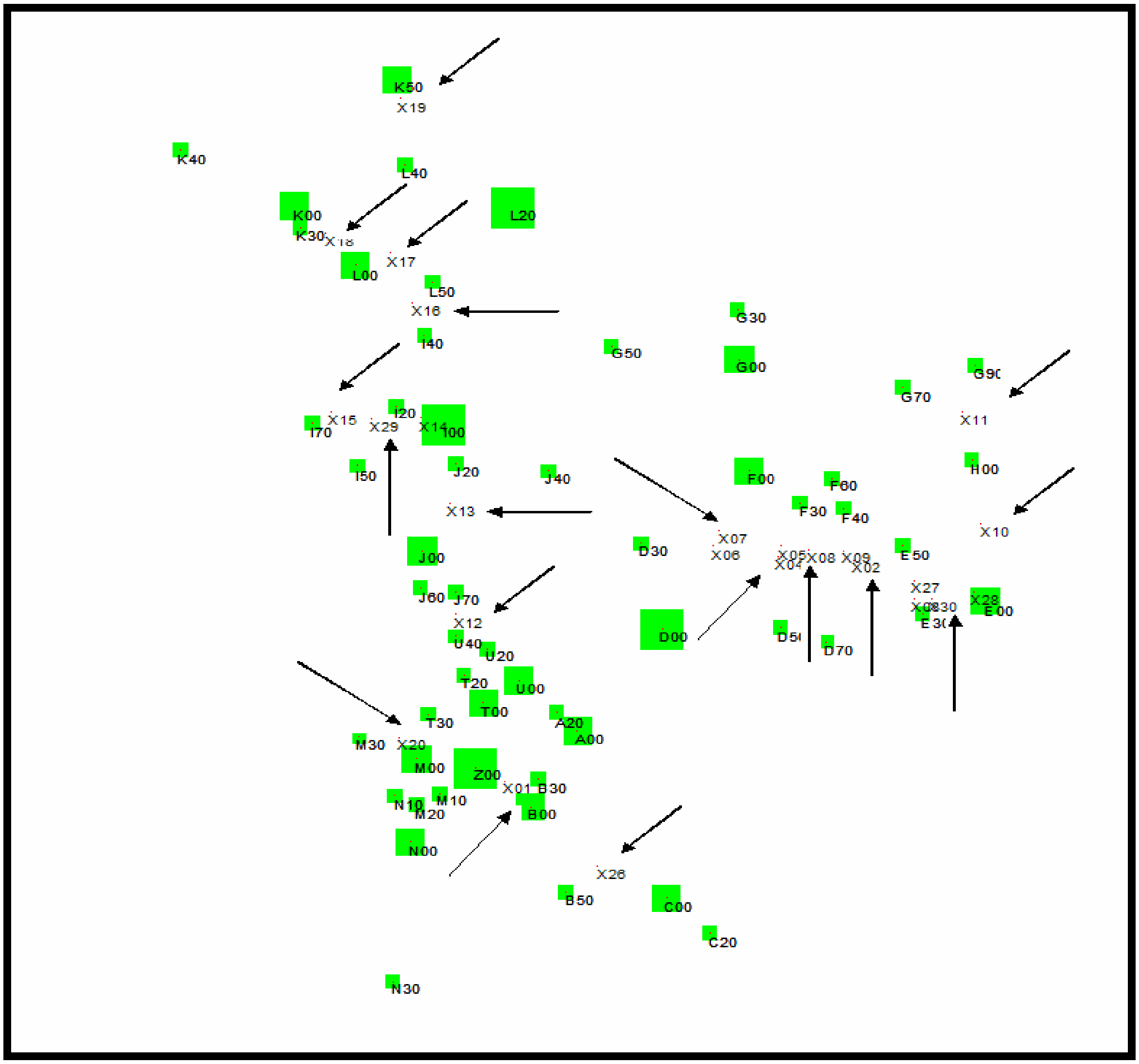

Figure 6.9. A graphical representation of optimal RSUlocations. Arrows have been added to clarify locations.

One of the more powerful tools on PLANITU is its ability to place RSU or remote subscriber units in the most optimal (maximizing profit and minimizing cost) locations. Each RSU has a capacity of 5,000 users [1]. Running one iteration in PLANITU will generate the optimal positions labeled with X preceding the number. Figure 6.9 illustrates the results. The RSU's are also represented with red dots which are hard to see. Arrows

have been inserted to show the exact positions for a section of the total network. This is a powerful tool for future network growth. Next will be a demonstration of the network sensitivity features. The sensitivity feature is a powerful tool for showing how the network responds to congestion, link failure, route failure and exchange node failure.

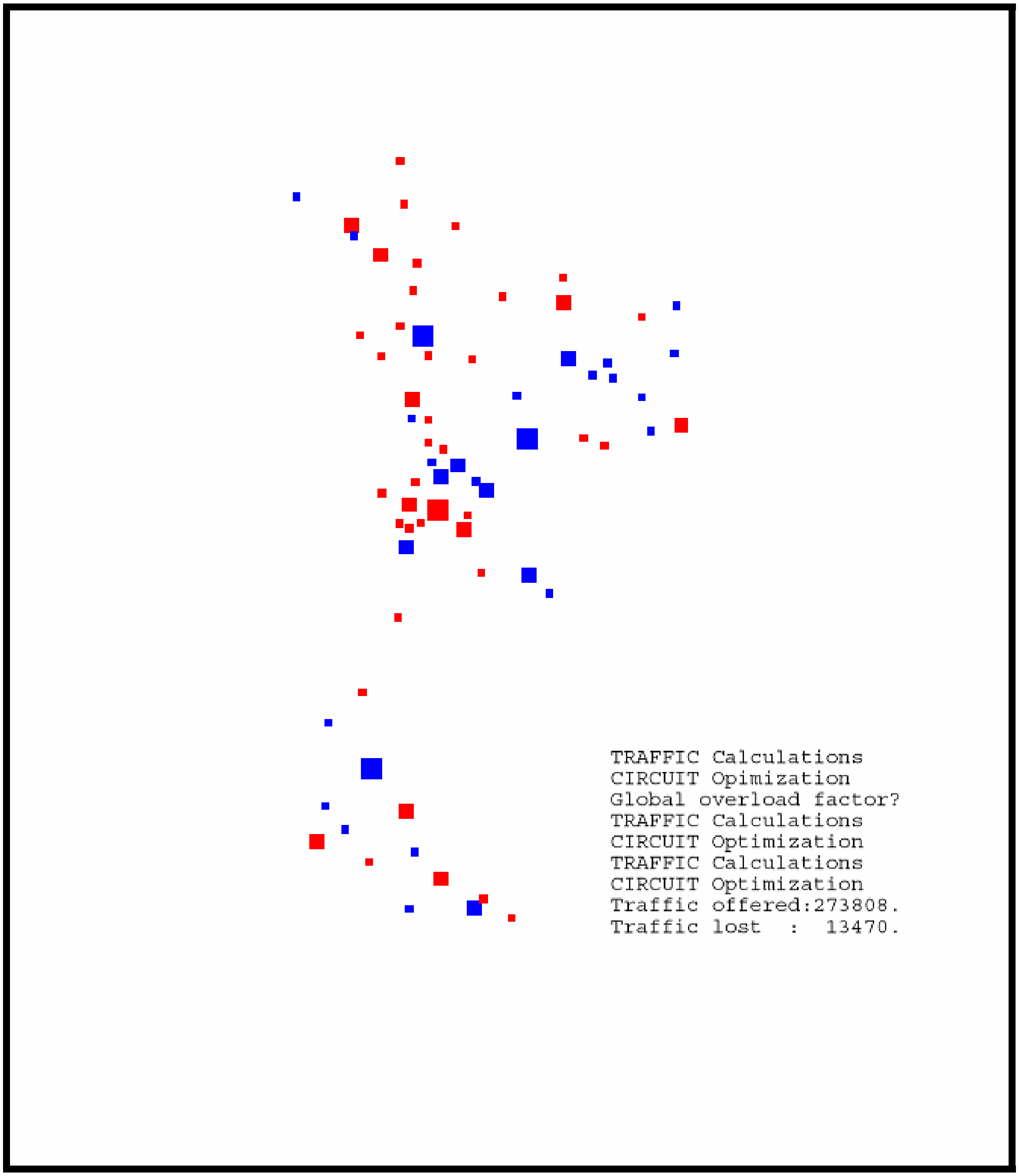

Figure 6.10. A graphical representation of the network being overloaded with calls. The factor used was a global overload factor of a 130% or 30% more than maximum capacity. Red squares shows areas of highest congestion.

Figure 6.10 shows the results of a global network overload. The overload factor used was 1.3, or 130% of network capacity. As can be seen the total traffic offered was 273,808 calls and 13,470 were lost or dropped (meaning a network busy signal). The graph interval was chosen to be 40, meaning show blue as 1/40 normal congestion levels and red as 40 times normal congestion. Thus red areas are the highest areas of congestion. This feature can also be used for an individual exchange node. Next will be an investigation if a link is out of service.

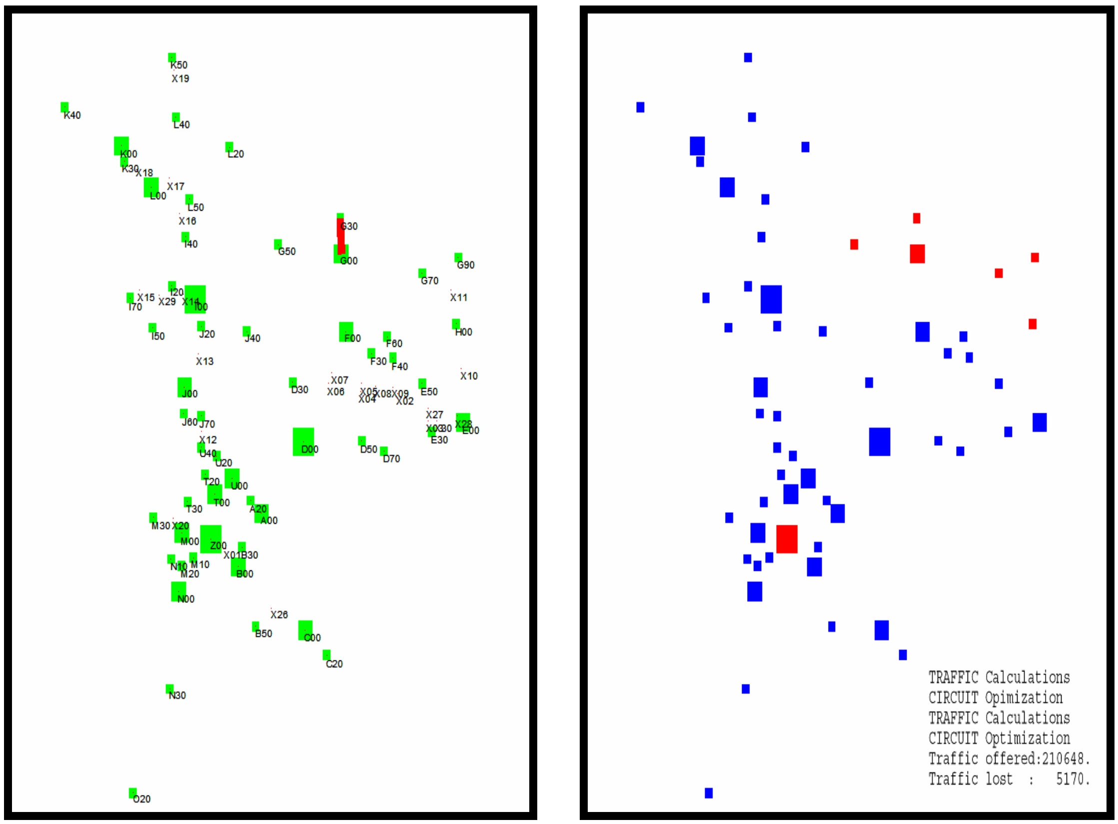

Figure 6.11. The graphical representation on the left is a generated network link failure between nodes 20 and 21. The representation on the right demonstrates the congestion effects on the network with red being the highest areas of congestion.

Figure 6.11 is an example of when a link is taken out of service. For this test link 20 to 21 was designated out of service (left side of figure). The results of the congestion due to this link failure are show on the right side of figure 6.11. A graphic factor of 30 was chosen (blue being areas 1/30 times normal congestion and red being 30 times normal congestion). Traffic offered was 210,648 calls and calls lost were predicted at 5,170. Next will be a demonstration of congestion levels if a traffic route is out of service.

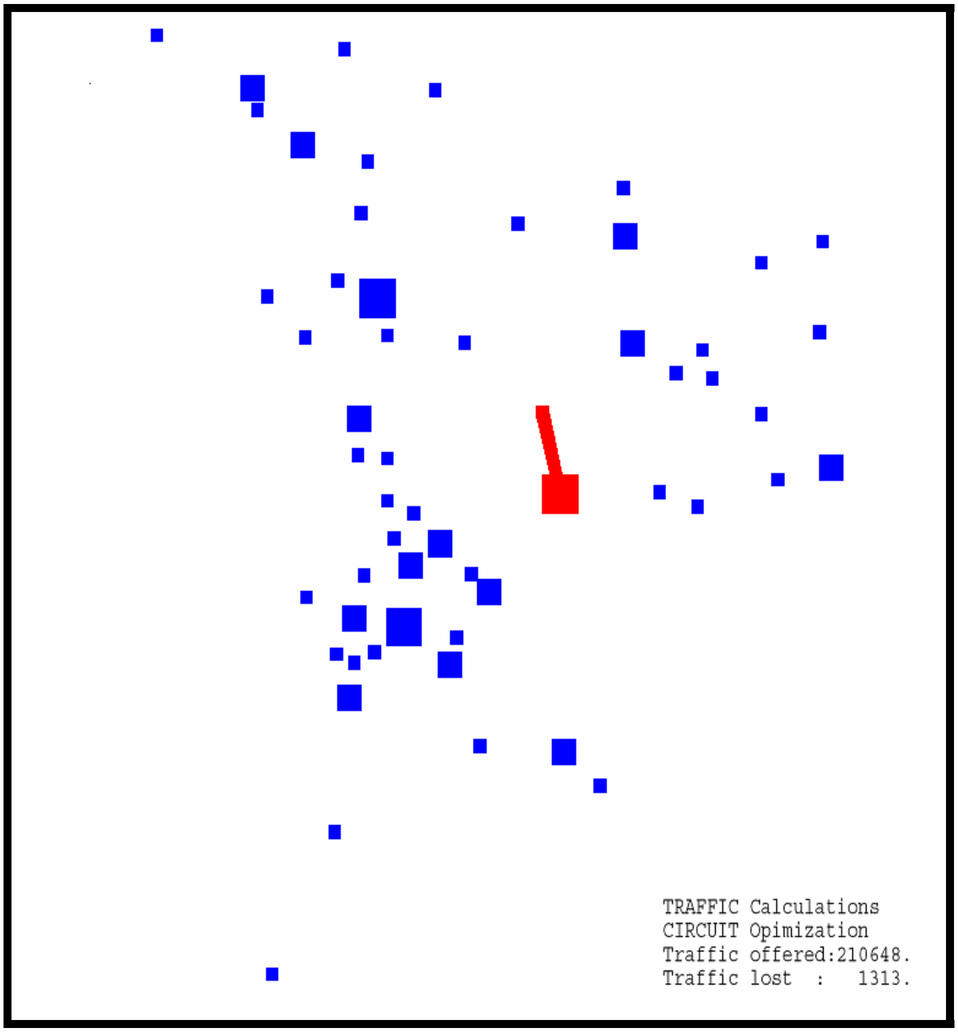

Figure 6.12. A graphical representation of a network route failure between nodes 9 and 10. Red shows highest areas of congestion.

Figure 6.12 is the result of a route failure between exchanges nine and ten. A graphic factor of 30 was chosen (blue is 1/30 congestion level and red is 30 times congestion levels where red is the highest levels of network congestion). The final example will be for an exchange node being out of service.

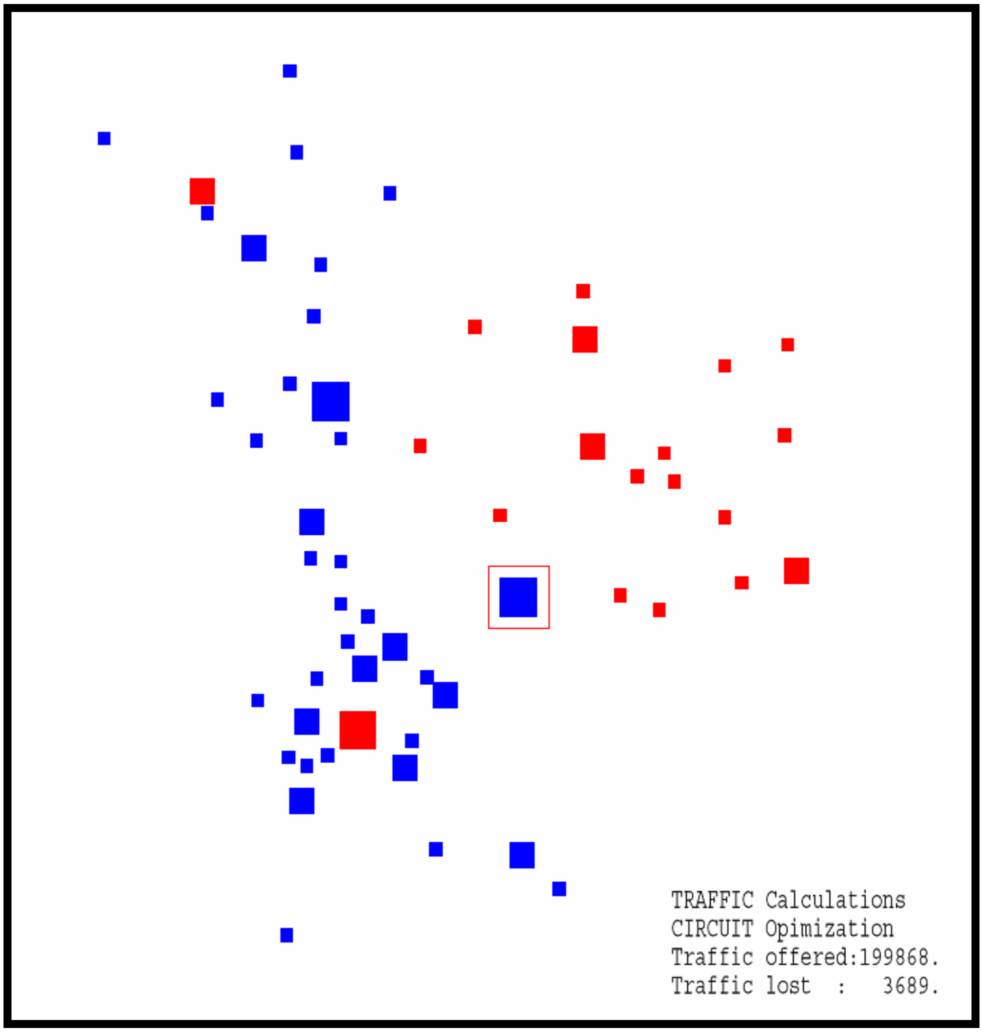

Figure 6.13. A graphical representation of a generated failed node exchange D00. D00 is represented with a red box around it. Areas with red squares show highest areas of network congestion.

In Figure 6.13 node nine, also known as D00, was chosen to fail (red box). Numerous other smaller exchanges were chosen but the smaller ones did not have much effect on the network. D00 was chosen because it is a major exchange node in a central region of the network. Traffic offered was 199,868 calls and 3,689 calls lost. A graphics factor of ten was used, once again blue is 1/10 normal congestion and red is 10 times normal congestion. This resulted in a major portion of the network experiencing network congestion. To a network planner or operator this would be an extremely helpful tool.

Over all the software performed well for the Thailand fixed network. All features work smoothly with little to no hiccups. PLANITU is at times unstable. On more than

one occasion the software locked up and rebooting was the only way to regain control. The next section will cover the simulation and analysis of the GSM model.

C. GSM NETWORK RESULTS AND ANALYSIS

One of the other goals of this paper was to investigate PLANITU's usability for a GSM network. This was a brand new feature for PLANITU 3.0. An analysis of the input data files shows that there was virtually no difference between the data input files of a fixed rural network and a GSM network, except for the distance between the nodes and the optimization rules. Many of the features demonstrated for the fixed Thailand network do not work for the GSM network. Numerous attempts and many hours of troubleshooting were spent which yielded no results. All network sensitivity tests yielded zero traffic offered and zero traffic lost regardless of network overload factors. Link failures, route failures and exchange node failures features did not work either. The only feature that worked correctly was the graphics. Below in Figure 6.14 is the network configuration. Green squares are MSC units, red lines are high traffic runs and green connecting lines are direct connections.

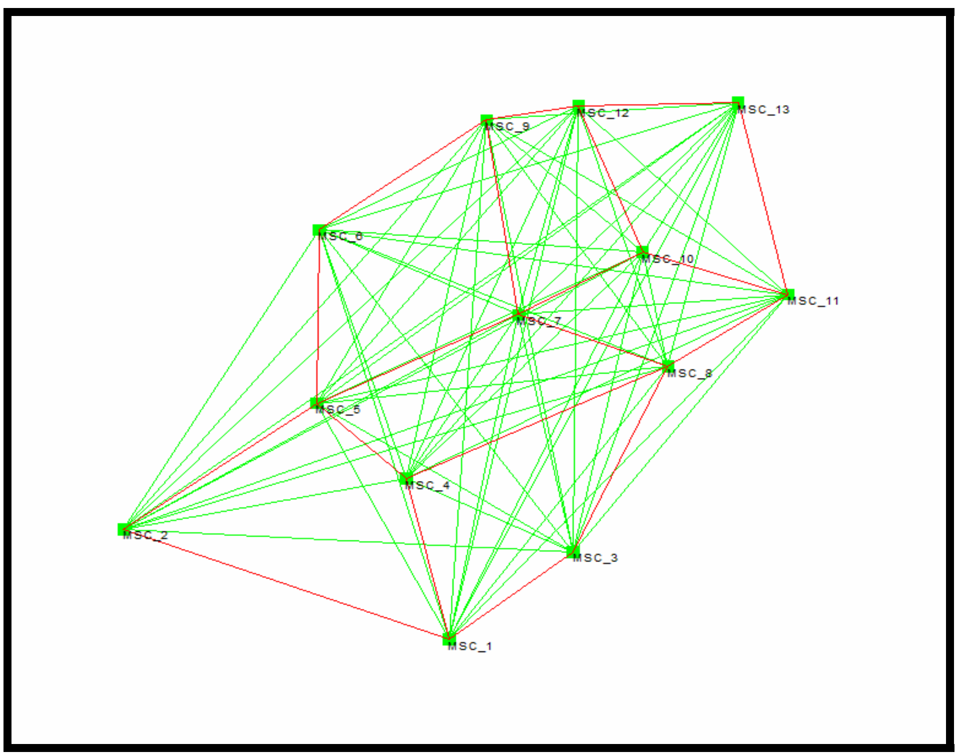

Figure 6.14. A graphical representation of a GSM network configuration. Red lines represent runs of high traffic links and green lines represent direct connections.

Overall analysis of PLANITU for GSM applications yielded poor results. Below is summary of reasons [12]:

- It does not use real world GSM planning and implementation scenarios.
- It is based on fixed networks for larger deployment where you have many MSCs in different locations.
- With the introduction of 3G/UMTS and VoIP, many operators are replacing MSCs with soft switches.
- The tool has many bugs, namely all network sensitivity features do not work.
- The GSM features were done very quickly and poorly and not tested for more than one network.
- Software was last updated in June 2002 and is showing its age.

D. CHAPTER SUMMARY

This chapter covered the results of FcMetro and PLANITU switch network simulations. FcMetro was used to generate a traffic matrix using many different input files. The traffic matrix generated could be specified for many different years in time. Two different switched networks were simulated and tested. The first was the Thailand national network, which was based on actual measured input data. The software performed quite well for the fixed network system. Numerous features, such as least cost routing and network sensitivity, were demonstrated to yield reasonable results [1]. The GSM network was also simulated, tested and evaluated. PLANITU did not perform well for GSM modeling. Many key features did not work, and there were numerous glitches and bugs found during software operation. Chapter VII will summarize the project, software performance and indicate future directions.

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VII. CONCLUSION AND FOLLOW-ON WORK

In this chapter, a summary of the project will be discussed along with software performance and areas for future work.

A. SUMMARIZATION

During the progression of this thesis, many areas were covered. Chapter II introduced the network planning process to include planning strategy, processes, and optimization structures were covered. Chapter III examined network architectures for fixed switched networks (Metro & Rural), GSM networks and traffic profiles. In chapter IV, traffic characterization and description were introduced, which also included the basic concepts for traffic engineering prediction, such as the Erlang-B loss Formula, Wilkinson's ERT method, traffic matrix estimation techniques and "Grade of Service". In chapter V, the specific details of the simulation environment were covered including basic system requirements, a model description for FcMetro, the Thailand fixed network, and a GSM network, which also included data requirements, data file formats and network specific data files contained in appendices A, B and C. Chapter VI presented the simulated results and analysis for each of the models and predicted network capacity and network response for the following cases: overload in traffic, link failure, route failure, and exchange node failure.

B. PLANITU PERFORMANCE

During the simulation processes, PLANITU performed well for the Thailand fixed network. All features worked properly and yielded reasonable results [1]. PLANITU demonstrated that it was capable of dealing with new traffic cases. The software was easy to use and was somewhat stable in operation. There were, of course, some problems with system deadlock situations. Graphic features were useful and easy to understand.

For the GSM model, PLANITU performed poorly. The GSM model input data files were almost exactly identical to the fixed model files, but yet most features were inoperable. An explanation could be found by examining the source code, but code was not available for study. Probably the most important problem is that PLANITU has not been updated since June 2002. GSM has changed by leaps and bounds since then to in-

clude the introduction of 3G/UMTS and VoIP, which the software does not address at all [12]. GSM was one of the last features released on the latest version of PLANITU 3.0 [1]; this could explain why the GSM feature did not work properly.

C. FUTURE WORK

There are many different network architectures to research, and each has different solutions. Each network planning case should be analyzed and dealt with by using more than just one planning tool [3]. PLANITU was chosen for its availability and cost. However, any real network planning case should be dealt with using other more powerful and modern tools available on the market.

PLANITU performed badly for GSM networks. Future work could include additional GSM modeling with more modern and powerful tools, such as either Switch NetWorks or ESG-Netcop [3]. These tools are produced overseas and are extremely expensive. There are no available trial versions for these tools and a license will have to be purchased, but may yield better results for GSM applications.

APPENDIX A. INPUT DATA FILES FOR FCMETRO

The following lines of text are the actual data input files for FcMetro. These input files will generate a traffic matrix to be used by PLANITU. All data is real data provided by Siemens Indonesia [2].

```
/*********************************************************************
                               FpFe.ASU
*********************************************************************/
 1.   1.   1.                        FPopulation  CEN   Time 4, 8, 12
1.   1.   1.                        FPopulation  TRI   Time 4, 8, 12
1.   1.   1.                        FPopulation  FND   Time 4, 8, 12
1.   1.   1.                        FPopulation  MRA   Time 4, 8, 12
1.   1.   1.                        FEmployee    CEN   Time 4, 8, 12
1.   1.   1.                        FEmplyee     TRI   Time 4, 8, 12
1.   1.   1.                        FEmployee    FND   Time 4, 8, 12
1.   1.   1.                        FEmployee    MRA   Time 4, 8, 12

/*********************************************************************
                               SubFc.ASU
*********************************************************************/
   20    Zones
  4    Traffic Atreas 'CEN' 'TRI' 'FND' 'MRA' 'INT' 'LD ' 'MOB'
  4    Categories 'RES ' 'BUS ' 'PBX ' 'CBX '
  2  3  5  4 PtsTime_TInt '1994' '1998' '2002' '2006' '2010'
STM       2  1
          3917   615    32    37
          7241   800    42    54
           378    21
         32214  5321
MRA       4  2
           801    94     5     5
          4971   479    25    22
           259    12
         15151  1867
LPO       4  3
           264    34     2     4
          1521   180     9     8
            79     5
         10377  1422
LQE       4  4
          2094   291    15    26
          7131   863    45    41
           620    38
         28319  4144
CTA       4  5
           618   173     9     8
          3667   402    21    14
           319    17
         20867  6158
NEM       4  6
           371    27     1     5
```

```
           4230   172     9    15
            368     7
           9465   733
SAO        4  7
            151    46     2     3
            975   121     6     3
             51     3
           2667   856
VEL        4  8
           1150    96     5    27
           5102   357    19    27
            444    16
          11168   983
LAM        4  9
           4036   925    49    47
           6603  1117    59    52
            689    58
          21046  6130
SLO        3 10
           1756   530    28    20
           7160  1021    54    50
            374    27
          15152  4815
SL2        3 11
           1680   507    27    15
           2754   656    35    34
            335    40
          24742  7862
FND        3 12
           8525  4284   179   164
          11042  6743   355   231
           1344   410
           8525  4463
TBT        2 13
           4516  1695    89    80
           5646  2645   139    80
            687   161
          30425 18753
SVI        2 14
           4731   760    24    75
           6392  2566   135    80
            667   134
          38428 21937
BOB        2 15
           4529   907    28    73
           4483  1979   104    75
            624   138
          26842 12350
SAJ        2 16
           4313  1048    55    78
           6195  1508    79    84
            539    66
          27646 10173
CNT        1 17
           6616 12651   807   167
           6075 13695   721   184
            951  1072
```

```
         32435 70667
CNU        1 18
         12026  7712   406   196
         14588  7804   411   205
          2283   611
         60418 40786
TRI        2 19
          4789  1658    69    83
          7001  2382   125   110
           852   145
         36951 19343
VMA        1 20
          9834  3844   202   109
         12359  4942   260   116
          1934   387
         47747 25258
```

/**

LDMob.ASU

**/

```
 1  1 0.009   0.009   0.009   0.009   0.014   0.014   0.014   0.014        CEN
                          Outgoing LD/ Mobile traffic
    2 0.019   0.019   0.019   0.019   0.029   0.029   0.029   0.029
    3 0.057   0.057   0.057   0.057   0.085   0.085   0.085   0.085
    4 0.057   0.057   0.057   0.057   0.085   0.085   0.085   0.085
 2  1 0.009   0.009   0.009   0.009   0.015   0.015   0.015   0.015        TRI
    2 0.014   0.014   0.014   0.014   0.023   0.023   0.023   0.023
    3 0.024   0.024   0.024   0.024   0.041   0.041   0.041   0.041
    4 0.024   0.024   0.024   0.024   0.041   0.041   0.041   0.041
 3  1 0.012   0.012   0.012   0.012   0.013   0.013   0.013   0.013        FND
    2 0.027   0.027   0.027   0.027   0.030   0.030   0.030   0.030
    3 0.017   0.017   0.017   0.017   0.019   0.019   0.019   0.019
    4 0.039   0.039   0.039   0.039   0.043   0.043   0.043   0.043
 4  1 0.005   0.005   0.005   0.005   0.009   0.009   0.009   0.009        MRA
    2 0.011   0.011   0.011   0.011   0.018   0.018   0.018   0.018
    3 0.011   0.011   0.011   0.011   0.019   0.019   0.019   0.019
    4 0.025   0.025   0.025   0.025   0.043   0.043   0.043   0.043
 1  1 0.008   0.008   0.008   0.008   0.003   0.003   0.003   0.003        CEN
                          Incoming LD/ Mobile traffic
    2 0.016   0.016   0.016   0.016   0.007   0.007   0.007   0.007
    3 0.047   0.047   0.047   0.047   0.021   0.021   0.021   0.021
    4 0.047   0.047   0.047   0.047   0.021   0.021   0.021   0.021
 2  1 0.007   0.007   0.007   0.007   0.004   0.004   0.004   0.004        TRI
    2 0.011   0.011   0.011   0.011   0.006   0.006   0.006   0.006
    3 0.020   0.020   0.020   0.020   0.010   0.010   0.010   0.010
    4 0.020   0.020   0.020   0.020   0.010   0.010   0.010   0.010
 3  1 0.011   0.011   0.011   0.011   0.004   0.004   0.004   0.004        FND
    2 0.026   0.026   0.026   0.026   0.009   0.009   0.009   0.009
    3 0.016   0.016   0.016   0.016   0.005   0.005   0.005   0.005
    4 0.037   0.037   0.037   0.037   0.012   0.012   0.012   0.012
 4  1 0.006   0.006   0.006   0.006   0.002   0.002   0.002   0.002        MRA
    2 0.011   0.011   0.011   0.011   0.005   0.005   0.005   0.005
    3 0.012   0.012   0.012   0.012   0.005   0.005   0.005   0.005
    4 0.027   0.027   0.027   0.027   0.012   0.012   0.012   0.012

      T=0     T=+4    T=+8    T=+12   T=0     T=+4    T=+8    T=+12
    ______________ LD ___________   ______________ MOB ____________
```

/***

Carate.ASU

***/

```
CEN  R 0.091   0.0     0.0     0.0
     B 0.186   0.0     0.0     0.0
     P 0.550   0.0     0.0     0.0
     C 0.550   0.0     0.0     0.0
TRI  R 0.091   0.0     0.0     0.0
     B 0.140   0.0     0.0     0.0
     P 0.250   0.0     0.0     0.0
     C 0.250   0.0     0.0     0.0
FND  R 0.076   0.0     0.0     0.0
     B 0.177   0.0     0.0     0.0
     P 0.110   0.0     0.0     0.0
     C 0.250   0.0     0.0     0.0
MRA  R 0.051   0.0     0.0     0.0
     B 0.104   0.0     0.0     0.0
     P 0.110   0.0     0.0     0.0
     C 0.250   0.0     0.0     0.0
_________________Everything below this line is a comment_______________
^Traffic Area
     ^Category  R-Residential,  B-Business,  P-PBX,  C-CoinBox  (Public
telephone)

       ^OCR T0 ^OCR T4 ^OCR T8 ^OCR12
OCR = Originating Calling Rate per telecommunication line

   This is file CaRate.Asu OCR for year O is given.
   You should forecast parameters for T = 4, T = 8 and T = 12 years
ahead.
```

/***

DBC.ASU

***/

```
  25  25  25  25    25  25  25  25    25  25  25  25    25  25  25  25
  25  25  25  25    25  25  25  25    25  25  25  25    25  25  25  25
  25  25  25  25    25  25  25  25    25  25  25  25    25  25  25  25
  25  25  25  25    25  25  25  25    25  25  25  25    25  25  25  25

 ---------------   ---------------   ---------------   ---------------
            T = 0             T = 4             T = 8             T =
12
RES BUS PBX Inet     RES BUS PBX Inet   RES BUS PBX Inet   RES BUS PBX
Inet
```

/***

W.ASU

***/

```
Res CEN    3 3 3 3 3 3 3 3 3 3 3 3          T=0
Res TRI    3 3 3 3 3 3 3 3 3 3 3 3
Res FND    3 3 3 3 3 3 3 3 3 3 3 3
Res MRA    3 3 3 3 3 3 3 3 3 3 3 3
Bus CEN    3 3 3 3 3 3 3 3 3 3 3 3
Bus TRI    3 3 3 3 3 3 3 3 3 3 3 3
Bus FND    3 3 3 3 3 3 3 3 3 3 3 3
```

Bus	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	FND	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
CB	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
CB	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
CB	FND	3	3	3	3	3	3	3	3	3	3	3	3	
CB	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
Res	CEN	3	3	3	3	3	3	3	3	3	3	3	3	T=4
Res	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
Res	FND	3	3	3	3	3	3	3	3	3	3	3	3	
Res	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	FND	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	FND	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
CB	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
CB	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
CB	FND	3	3	3	3	3	3	3	3	3	3	3	3	
CB	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
Res	CEN	3	3	3	3	3	3	3	3	3	3	3	3	T=8
Res	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
Res	FND	3	3	3	3	3	3	3	3	3	3	3	3	
Res	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	FND	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	FND	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
CB	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
CB	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
CB	FND	3	3	3	3	3	3	3	3	3	3	3	3	
CB	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
Res	CEN	3	3	3	3	3	3	3	3	3	3	3	3	T=12
Res	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
Res	FND	3	3	3	3	3	3	3	3	3	3	3	3	
Res	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	FND	3	3	3	3	3	3	3	3	3	3	3	3	
Bus	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	FND	3	3	3	3	3	3	3	3	3	3	3	3	
PBX	MRA	3	3	3	3	3	3	3	3	3	3	3	3	
CB	CEN	3	3	3	3	3	3	3	3	3	3	3	3	
CB	TRI	3	3	3	3	3	3	3	3	3	3	3	3	
CB	FND	3	3	3	3	3	3	3	3	3	3	3	3	
CB	MRA	3	3	3	3	3	3	3	3	3	3	3	3	

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APPENDIX B. INPUT DATA FILES THAILAND NETWORK

The following lines of text are the actual data input files for the Thailand National network. All data is real data provided by Siemens Indonesia [2].

```
/**********************************************************************
                              Build..tha
**********************************************************************/
  3 conversion tables subs. to floor space
 20000.   0.1   5000. 1.     0.   275.  anal
 50000.   195. 10000. 1.     0.    65.  dig
  2000.     2.   128. 1.     0.     2.  RSU
  1 new buildings
  3000.     0.
  4 extensions
   300. 12000.
   500. 18500.
   700. 25000.
   900. 31000.
AnlgDgtlRSU
```

```
/**********************************************************************
                              Cosw..tha
**********************************************************************/
   1  1  switching tables
 3.462    3.462
Dgtl
```

```
/**********************************************************************
                              Excost..tha
**********************************************************************/
  1 exchange costs                                  Subs +Circs
      0.0       0.0       0.0    7780.00  DigitalT (0 +  12000)
  1 exchange sizes
 1. 1.     0. 12000.     0.  DigitalT
DigT
```

```
/**********************************************************************
                              Exdefd.GSM
**********************************************************************/
70 exchanges
Z00       1  0.0    0.0    3  2  2  0      0.      0.
A00       2  0.0    0.0    2  2  2  1      0.      0.
A20       3  0.0    0.0    1  2  2  2      0.      0.
B00       4  0.0    0.0    2  2  2  1      0.      0.
B30       5  0.0    0.0    1  2  2  4      0.      0.
B50       6  0.0    0.0    1  2  2  4      0.      0.
C00       7  0.0    0.0    2  2  2  1      0.      0.
C20       8  0.0    0.0    1  2  2  7      0.      0.
D00       9  0.0    0.0    3  2  2  0      0.      0.
D30      10  0.0    0.0    1  2  2  9      0.      0.
```

D50	11	0.0	0.0	1	2	2	9	0.	0.
D70	12	0.0	0.0	1	2	2	9	0.	0.
E00	13	0.0	0.0	2	2	2	9	0.	0.
E30	14	0.0	0.0	1	2	2	13	0.	0.
E50	15	0.0	0.0	1	2	2	13	0.	0.
F00	16	0.0	0.0	2	2	2	9	0.	0.
F30	17	0.0	0.0	1	2	2	16	0.	0.
F40	18	0.0	0.0	1	2	2	16	0.	0.
F60	19	0.0	0.0	1	2	2	16	0.	0.
G00	20	0.0	0.0	2	2	2	9	0.	0.
G30	21	0.0	0.0	1	2	2	20	0.	0.
G50	22	0.0	0.0	1	2	2	20	0.	0.
G70	23	0.0	0.0	1	2	2	20	0.	0.
G90	24	0.0	0.0	1	2	2	20	0.	0.
H00	25	0.0	0.0	1	2	2	20	0.	0.
I00	26	0.0	0.0	3	2	2	0	0.	0.
I20	27	0.0	0.0	1	2	2	26	0.	0.
I40	28	0.0	0.0	1	2	2	26	0.	0.
I50	29	0.0	0.0	1	2	2	26	0.	0.
I70	30	0.0	0.0	1	2	2	26	0.	0.
J00	31	0.0	0.0	2	2	2	26	0.	0.
J20	32	0.0	0.0	1	2	2	31	0.	0.
J40	33	0.0	0.0	1	2	2	31	0.	0.
J60	34	0.0	0.0	1	2	2	31	0.	0.
J70	35	0.0	0.0	1	2	2	31	0.	0.
K00	36	0.0	0.0	2	2	2	26	0.	0.
K30	37	0.0	0.0	1	2	2	36	0.	0.
K40	38	0.0	0.0	1	2	2	36	0.	0.
K50	39	0.0	0.0	1	2	2	36	0.	0.
L00	40	0.0	0.0	2	2	2	26	0.	0.
L20	41	0.0	0.0	1	2	2	40	0.	0.
L40	42	0.0	0.0	1	2	2	40	0.	0.
L50	43	0.0	0.0	1	2	2	40	0.	0.
M00	44	0.0	0.0	2	2	2	1	0.	0.
M10	45	0.0	0.0	1	2	2	44	0.	0.
M20	46	0.0	0.0	1	2	2	44	0.	0.
M30	47	0.0	0.0	1	2	2	44	0.	0.
N00	48	0.0	0.0	2	2	2	1	0.	0.
N10	49	0.0	0.0	1	2	2	48	0.	0.
N30	50	0.0	0.0	1	2	2	48	0.	0.
O00	51	0.0	0.0	3	2	2	0	0.	0.
O20	52	0.0	0.0	1	2	2	51	0.	0.
O30	53	0.0	0.0	1	2	2	51	0.	0.
P00	54	0.0	0.0	2	2	2	51	0.	0.
P10	55	0.0	0.0	1	2	2	54	0.	0.
Q00	56	0.0	0.0	2	2	2	51	0.	0.
Q20	57	0.0	0.0	1	2	2	56	0.	0.
Q30	58	0.0	0.0	1	2	2	56	0.	0.
R00	59	0.0	0.0	2	2	2	51	0.	0.
R20	60	0.0	0.0	1	2	2	59	0.	0.
R30	61	0.0	0.0	1	2	2	59	0.	0.
S00	62	0.0	0.0	2	2	2	51	0.	0.
S10	63	0.0	0.0	1	2	2	62	0.	0.
S20	64	0.0	0.0	1	2	2	62	0.	0.
T00	65	0.0	0.0	2	2	2	1	0.	0.
T20	66	0.0	0.0	1	2	2	65	0.	0.
T30	67	0.0	0.0	1	2	2	65	0.	0.

```
U00       68  0.0    0.0    2  2  2  1      0.       0.
U20       69  0.0    0.0    1  2  2 68      0.       0.
U40       70  0.0    0.0    1  2  2 68      0.       0.
  4  levels
  1  1  1  1  0  0     Lev1
  2  2  2  1  0  0     Lev2
  3  3  3  1  0  0     Lev3
  4  4  4  2  0  0     Lev4
 3  exchange types
  1  1  1  1  1  1  1  1  2     analog
  1  1  1  2  2  2  2  1  3     dig
  1  3  1  2  3  1  2  3  3     RSU
  3  optimization rules
  1  1
  0  1
  0  0
```

/***

Gos.tha

***/

```
  4  0  GOS matrix
 0.01  0.01  0.01  0.01  0.005
 0.01  0.01  0.01  0.01  0.002
 0.01  0.01  0.01  0.01  0.002
 0.01  0.01  0.01  0.01  0.002
 0.000 0.000 0.000 0.000 0.000
Lev1Lev2Lev3Lev4
```

/***

Links.tha

***/

```
  1 71 40.4  1 1.   1.    0  0 1000  1    Z00  X01
 71  4 26.4  1 1.   1.    0  0    0  2    X01  B00
 71  5 27.7  1 1.   1.    0  0    0  2    X01  B30
  5  4 33.2  1 1.   1.    0  0    0  2    B30  B00
  4  6100.8  1 1.   1.    0  0    0  2    B00  B50
  5 96118.2  1 1. 999.    0  0    0  2    B30  X26
  6 96 15.1  1 1.   1.    0  0    0  2    B50  X26
 96  7 74.9  1 1.  1.150  0  0    0  1    X26  C00
  7  8 74.8  1 1.  0.884  0  0    0  1    C00  C20
  5  2 52.7  1 1.  1.277  0  0    0  2    B30  A00
  2  3 24.0  1 1.  1.0    0  0    0  1    A00  A20
  3 68 61.0  1 1.  1.0    0  0    0  1    A20  U00
  2  9124.0  1 1.  1.317  0  0    0  1    A00  D00
 68  9138.0  1 1.  1.0    0  0    0  1    U00  D00
  9 11109.1  1 1.  1.0    0  0    0  1    D00  D50
  9 10 99.3  1 1.  1.0    0  0    0  1    D00  D30
 11 12 32.7  1 1.  1.324  0  0    0  1    D50  D70
 12 14 94.0  1 1.  1.0    0  0    0  1    D70  E30
 14 13 57.9  1 1.  1.     0  0    0  1    E30  E00
  9 77158.7  1 1.  1.0    0  0    0  1    D00  X07
 10 76 71.0  1 1.  1.0    0  0    0  1    D30  X06
 77 16 48.2  1 1.  1.0    0  0    0  1    X07  F00
 16 17 56.6  1 1.  1.053  0  0    0  1    F00  F30
 17 19 35.0  1 1.  1.0    0  0    0  1    F30  F60
```

```
 17 18 40.3  1 1.  1.0    0  0    0  1    F30  F40
 18 15 64.2  1 1.  1.0    0  0    0  1    F40  E50
 15 98 92.3  1 1.  1.0    0  0    0  1    E50  X28
 98 13 33.5  1 1.  1.0    0  0    0  1    X28  E00
 11 74 62.0  1 1.  1.0    0  0    0  1    D50  X04
 74 76 67.4  1 1.  1.0    0  0    0  1    X04  X06
 74 75 29.0  1 1.  1.0    0  0    0  1    X04  X05
 75 17 53.8  1 1.  1.0    0  0    0  1    X05  F30
 74 78 38.0  1 1.  1.0    0  0    0  1    X04  X08
 75 78 38.5  1 1.  1.0    0  0    0  1    X05  X08
 78 79 25.0  1 1.  1.0    0  0    0  1    X08  X09
 12 72 52.2  1 1.  1.0    0  0    0  1    D70  X02
 72 79 39.0  1 1.  1.0    0  0    0  1    X02  X09
 79 18 46.5  1 1.  1.0    0  0    0  1    X09  F40
 72 73 52.1  1 1.  1.0    0  0    0  1    X02  X03
 73 97 23.5  1 1.  1.0    0  0    0  1    X03  X27
 73100 27.0  1 1.  1.0    0  0    0  1    X03  X30
100 97 35.7  1 1.  1.0    0  0    0  1    X30  X27
 14100 18.3  1 1.  1.0    0  0    0  1    E30  X30
 97 15 31.0  1 1.  1.0    0  0    0  1    X27  E50
 16 20111.9  1 1.  1.003  0  0    0  1    F00  G00
 19 20142.8  1 1.  1.0    0  0    0  1    F60  G00
 20 21 51.8  1 1.  1.0    0  0    0  1    G00  G30
 20 22125.7  1 1.  1.003  0  0    0  1    G00  G50
 21 24296.2  1 1.  1.0    0  0    0  1    G30  G90
 20 23153.6  1 1.  1.014  0  0    0  1    G00  G70
 23 24 77.4  1 1.  1.0    0  0    0  1    G70  G90
 23 81 50.5  1 1.  1.0    0  0    0  1    G70  X11
 81 24 44.8  1 1.  1.0    0  0    0  1    X11  G90
 81 25 46.8  1 1.  1.0    0  0    0  1    X11  H00
 25 80 33.3  1 1.  1.0    0  0    0  1    H00  X10
 15 80121.9  1 1.  1.0    0  0    0  1    E50  X10
 98 80100.0  1 1.  1.0    0  0    0  1    X28  X10
  1 68102.2  1 1.  1.0    0  1    0  1    Z00  U00
  4  1
  1 65 71.3  1 1.  1.0    0  0    0  1    Z00  T00
 68 65 41.2  1 1.  1.0    0  0    0  1    U00  T00
 65 44 83.6  1 1.  1.0    0  0    0  1    T00  M00
 44 90 22.7  1 1.  1.0    0  0    0  1    M00  X20
 90 67 54.8  1 1.  1.0    0  0    0  1    X20  T30
 65 67 51.1  1 1.  1.0    0  0    0  1    T00  T30
 65 66 27.8  1 1.  1.0    0  0    0  1    T00  T20
 66 67 39.0  1 1.  1.0    0  0    0  1    T20  T30
 67 82 31.3  1 1.  1.0    0  0    0  1    T30  X12
 66 70 35.2  1 1.  1.0    0  0    0  1    T20  U40
 82 70 36.0  1 1.  1.0    0  0    0  1    X12  U40
 68 69 41.4  1 1.  1.060  0  0    0  1    U00  U20
 69 70 27.6  1 1.  1.0    0  0    0  1    U20  U40
 69 31115.7  1 1.  1.0    0  0    0  1    U20  J00
 70 35 43.5  1 1.  1.0    0  0    0  1    U40  J70
 82 35 48.8  1 1.  1.0    0  0    0  1    X12  J70
 35 34 23.2  1 1.  1.0    0  0    0  1    J70  J60
 34 31 37.6  1 1.  1.0    0  0    0  1    J60  J00
 31 29105.5  1 1.  1.0    0  0    0  1    J00  I50
 31 83 46.2  1 1.  1.011  0  0    0  1    J00  X13
 83 33 97.2  1 1.  1.0    0  0    0  1    X13  J40
 83 32 47.3  1 1.  1.036  0  0    0  1    X13  J20
```

```
32 26 40.5  1 1.  1.002  0  0    0  1    J20  I00
32 29 87.3  1 1.  1.0    0  0    0  1    J20  I50
26 22201.2  1 1.  1.0    0  1    0  1    I00  G50
 1  1
29 85 21.0  1 1.  1.0    0  0    0  1    I50  X15
85 30 60.5  1 1.  1.0    0  0    0  1    X15  I70
30 40182.0  1 1.  1.0    0  0    0  1    I70  L00
26 84 35.5  1 1.  1.0    0  0    0  1    I00  X14
84 99 23.2  1 1.  1.0    0  0    0  1    X14  X29
99 85 30.5  1 1.  1.0    0  0    0  1    X29  X15
99 27 19.9  1 1.  1.0    0  0    0  1    X29  I20
84 27 17.5  1 1.  1.0    0  0    0  1    X14  I20
27 28 84.9  1 1.  1.0    0  0    0  1    I20  I40
26 28 93.0  1 1.  1.043  0  0    0  1    I00  I40
28 86 34.7  1 1.  1.0    0  0    0  1    I40  X16
86 43 28.3  1 1.  1.0    0  0    0  1    X16  L50
43 41103.4  1 1.  1.0    0  0    0  1    L50  L20
86 87 42.5  1 1.  1.0    0  0    0  1    X16  X17
40 87 30.8  1 1.  1.0    0  0    0  1    L00  X17
40 88 42.3  1 1.  1.0    0  0    0  1    L00  X18
88 36 48.7  1 1.  1.0    0  0    0  1    X18  K00
88 37 28.5  1 1.  1.0    0  0    0  1    X18  K30
37 36 24.0  1 1.  1.0    0  0    0  1    K30  K00
36 38156.2  1 1.  1.0    0  0    0  1    K00  K40
87 42104.9  1 1.  1.0    0  0    0  1    X17  L40
42 89 84.5  1 1.  1.0    0  0    0  1    L40  X19
89 39 10.7  1 1.  1.0    0  0    0  1    X19  K50
36 89171.6  1 1.  1.0    0  0    0  1    K00  X19
 1 44 50.0  1 1.  1.022  0  1    0  1    Z00  M00
 5  1
90 47 58.3  1 1.  1.0    0  0    0  1    X20  M30
47 49 75.3  1 1.  1.0    0  0    0  1    M30  N10
44 49 40.7  1 1.  1.0    0  0    0  1    M00  N10
44 45 37.9  1 1.  1.0    0  0    0  1    M00  M10
45 46 32.7  1 1.  1.0    0  0    0  1    M10  M20
46 49 25.0  1 1.  1.0    0  0    0  1    M20  N10
49 48 48.5  1 1.  1.012  0  0    0  1    N10  N00
46 48 34.5  1 1.  1.0    0  0    0  1    M20  N00
48 50135.5  1 1.  1.093  0  0    0  1    N00  N30
50 52161.7  1 1.  1.007  0  0    0  1    N30  O20
52 53 91.2  1 1.  1.0    0  0    0  1    O20  O30
52 51156.6  1 1.  1.003  0  0    0  1    O20  O00
51 91  7.2  1 1.  1.0    0  0    0  1    O00  X21
91 95158.9  1 1.  1.0    0  0    0  1    X21  X25
95 54 27.1  1 1.  1.0    0  0    0  1    X25  P00
95 55 38.3  1 1.  1.0    0  0    0  1    X25  P10
91 92117.8  1 1.  1.0    0  0    0  1    X21  X22
92 93 43.5  1 1.  1.0    0  0    0  1    X22  X23
51 56141.4  1 1.  1.0    0  0    0  1    O00  Q00
56 93 34.0  1 1.  1.0    0  0    0  1    Q00  X23
92 57 73.1  1 1.  1.0    0  0    0  1    X22  Q20
57 58103.7  1 1.  1.0    0  0    0  1    Q20  Q30
57 60136.3  1 1.  1.0    0  0    0  1    Q20  R20
93 61 56.0  1 1.  1.193  0  0    0  1    X23  R30
61 94 51.3  1 1.  1.109  0  0    0  1    R30  X24
94 60 67.0  1 1.  1.0    0  0    0  1    X24  R20
94 59 31.8  1 1.  1.0    0  0    0  1    X24  R00
```

```
 93 59139.0  1 1.  1.0    0  0    0  1    X23  R00
 59 63 84.7  1 1.  1.0    0  0    0  1    R00  S10
 63 62 43.0  1 1.  1.0    0  0    0  1    S10  S00
 63 64 84.6  1 1.  1.0    0  0    0  1    S10  S20
 76 77 17.8  1 1.  1.0    0  0    0  1    X06  X07
```

/**

Newexd..tha

**/

```
  4 -1  3 21  new exchanges
  1  2  2  0  Lev1
  2  2  2  0  Lev2
  3  2  2  0  Lev3
  4  2  2  0  Lev4
  1  Z00
  2  A00
  4  B00
  7  C00
  9  D00
 13  E00
 16  F00
 20  G00
 26  I00
 31  J00
 36  K00
 40  L00
 44  M00
 48  N00
 51  O00
 54  P00
 56  Q00
 59  R00
 62  S00
 65  T00
 68  U00
```

/**

Nodes95.tha

**/

```
  1 S  Nodes year 1995
Format:(i3,i4,a1,i2,i3,a1,i2,I3,1x,2i3,f5.0,3f6.1,5x,a6)
  1 100E31 13N45  0.  1        4316.35180.9   0.0     Z00   BANGKOK
  2 101E23 14N05  0.  2         162.0 168.4   0.0     A00   PRACHINBURI
  3 101E12 14N15  0.  3          71.2  72.6   0.0     A20   NAKHONNAYOK
  4 100E59 13N24  0.  4         957.5 917.1   0.0     B00   CHON BURI
        5  101E03  13N39   0.   5            357.4  343.5    0.0       B30
HACHOENGSAO
        6  101E17  12N38   0.   6            384.5  371.8    0.0       B50
RAYONG
        7  102E08  12N35   0.   7            125.3  115.2    0.0       C00
CHANTHABURI
        8 102E30 12N16  0.  8          75.4  74.3   0.0     C20   TRAT
        9  102E06  15N00   0.   9            578.3  511.6    0.0       D00
NAKHONRATCH
 10 101E55 15N46  0. 10         138.7 132.7   0.0     D30   CHAIYAPHUM
```

11	103E06	15N01	0. 11	161.2	153.2	0.0	D50	BURI RAM
12	103E29	14N53	0. 12	187.3	180.7	0.0	D70	SURIN
13	104E50	15N15	0. 13	299.4	282.3	0.0	E00	UBONRATCHAT
14	104E18	15N08	0. 14	87.6	84.6	0.0	E30	SI SA KET
15	104E08	15N45	0. 15	106.6	103.8	0.0	E50	YASOTHON
16	102E50	16N25	0. 16	479.6	443.4	0.0	F00	KHON KAEN
17	103E16	16N08	0. 17	95.0	88.7	0.0	F30	MAHAARAKHAM
18	103E38	16N05	0. 18	112.5	106.3	0.0	F40	ROI ET
19	103E32	16N21	0. 19	101.5	97.4	0.0	F60	KALASIN
20	102E45	17N25	0. 20	587.2	479.4	0.0	G00	UDON THANI
21	102E44	17N52	0. 21	256.9	246.2	0.0	G30	NONG KHAI
22	101E40	17N32	0. 22	272.7	258.0	0.0	G50	LOEI
23	104E08	17N10	0. 23	100.6	162.5	0.0	G70	SAKHONNAKHN
24	104E45	17N22	0. 24	92.2	86.8	0.0	G90	NAKHONPHANO
25	104E43	16N31	0. 25	111.8	106.4	0.0	H00	MUKDAHAN
26	100E15	16N50	0. 26	368.7	353.2	0.0	I00	PHITSANULOK
27	99E51	17N00	0. 27	181.7	178.0	0.0	I20	SUKHOTHAI
28	100E05	17N38	0. 28	192.0	186.0	0.0	I40	UTTARADIT
29	99E31	16N28	0. 29	264.9	255.5	0.0	I50	KAMPHAENGPH
30	99E08	16N51	0. 30	221.8	221.3	0.0	I70	TAK
31	100E04	15N42	0. 31	338.5	335.0	0.0	J00	NAKHONSAWAN
32	100E21	16N29	0. 32	152.8	149.1	0.0	J20	PHICHIT
33	101E08	16N25	0. 33	250.8	256.4	0.0	J40	PHETCHABUN
34	100E03	15N22	0. 34	54.9	54.0	0.0	J60	UTHAI THANI
35	100E21	15N20	0. 35	113.4	110.9	0.0	J70	CHAI NAT
36	98E59	18N48	0. 36	759.3	585.5	0.0	K00	CHIANG MAI
37	99E02	18N36	0. 37	121.4	114.2	0.0	K30	LAMPHUN
38	98E01	19N18	0. 38	36.8	34.6	0.0	K40	MAE HONGSON
39	99E51	19N56	0. 39	261.9	251.9	0.0	K50	CHIANG RAI
40	99E30	18N16	0. 40	291.9	282.3	0.0	L00	LAMPANG
41	100E50	18N47	0. 41	75.2	73.4	0.0	L20	NAN
42	99E55	19N10	0. 42	94.9	89.7	0.0	L40	PHAYAO
43	100E09	18N07	0. 43	186.6	180.7	0.0	L50	PHRAE
44	100E01	13N50	0. 44	787.8	764.8	0.0	M00	NAKHONATHOM
45	100E13	13N31	0. 45	490.9	483.7	0.0	M10	SAMUTSAKHON
46	100E01	13N25	0. 46	96.3	95.0	0.0	M20	SAMUTSONGKH
47	99E32	14N02	0. 47	492.0	481.9	0.0	M30	KANCHANABUR
48	99E58	13N05	0. 48	318.4	320.6	0.0	N00	PHETCHABURI
49	99E50	13N30	0. 49	492.6	468.4	0.0	N10	RATCHABURI
50	99E49	11N50	0. 50	319.8	311.5	0.0	N30	PRACHUAPKHI
51	99E20	9N09	0. 51	352.6	325.9	0.0	O00	SURAT THANI
52	99E11	10N30	0. 52	181.2	175.0	0.0	O20	CHUMPHON
53	98E35	9N58	0. 53	151.8	146.9	0.0	O30	RANONG
54	98E22	7N52	0. 54	217.7	188.6	0.0	P00	PHUKET
55	98E31	8N29	0. 55	92.3	86.6	0.0	P10	PHANGNGA
56	99E58	8N24	0. 56	319.0	302.6	0.0	Q00	NAKHON SIAM
57	99E18	7N30	0. 57	238.8	223.2	0.0	Q20	TRANG
58	98E52	8N04	0. 58	65.2	62.4	0.0	Q30	KRABI
59	100E35	7N12	0. 59	494.2	417.4	0.0	R00	SONGKHLA
60	100E01	6N40	0. 60	109.1	102.5	0.0	R20	SATUN
61	100E06	7N40	0. 61	81.3	77.3	0.0	R30	PHATTHALUNG
62	101E10	6N40	0. 62	195.2	185.4	0.0	S00	YALA
63	101E20	6N50	0. 63	206.4	197.1	0.0	S10	PATTANI
64	101E50	6N30	0. 64	206.6	195.2	0.0	S20	NARATHIWAT
65	100E35	14N20	0. 65	327.2	336.2	0.0	T00	AYUTTHAYA
66	100E25	14N35	0. 66	101.8	103.9	0.0	T20	ANG THONG
67	100E07	14N14	0. 67	251.1	248.7	0.0	T30	SUPHAN BURI

```
 68 100E53 14N32  0. 68         413.8 417.7   0.0     U00   SARABURI
 69 100E37 14N49  0. 69         365.4 359.8   0.0     U20   LOP BURI
 70 100E21 14N56  0. 70         219.7 217.0   0.0     U40   SING BURI
 71 100E46 13N38  0.  1           0.0   0.0   0.0     X01
 72 103E43 15N37  0.  1           0.0   0.0   0.0     X02
 73 104E14 15N16  0.  1           0.0   0.0   0.0     X03
 74 103E 5 15N39  0.  1           0.0   0.0   0.0     X04
 75 103E 6 15N45  0.  1           0.0   0.0   0.0     X05
 76 102E32 15N45  0.  1           0.0   0.0   0.0     X06
 77 102E35 15N53  0.  1           0.0   0.0   0.0     X07
 78 103E20 15N43  0.  1           0.0   0.0   0.0     X08
 79 103E38 15N42  0.  1           0.0   0.0   0.0     X09
 80 104E48 15N57  0.  1           0.0   0.0   0.0     X10
 81 104E38 16N57  0.  1           0.0   0.0   0.0     X11
 82 100E21 15N 8  0.  1           0.0   0.0   0.0     X12
 83 100E18 16N 8  0.  1           0.0   0.0   0.0     X13
 84 100E 3 16N54  0.  1           0.0   0.0   0.0     X14
 85  99E18 16N57  0.  1           0.0   0.0   0.0     X15
 86  99E59 17N56  0.  1           0.0   0.0   0.0     X16
 87  99E48 18N23  0.  1           0.0   0.0   0.0     X17
 88  99E15 18N33  0.  1           0.0   0.0   0.0     X18
 89  99E53 19N46  0.  1           0.0   0.0   0.0     X19
 90  99E52 14N 1  0.  1           0.0   0.0   0.0     X20
 91  98E35  8N58  0.  1           0.0   0.0   0.0     X21
 92  99E17  7N53  0.  1           0.0   0.0   0.0     X22
 93 100E17  8N 2  0.  1           0.0   0.0   0.0     X23
 94 100E26  7N16  0.  1           0.0   0.0   0.0     X24
 95  98E26  8N11  0.  1           0.0   0.0   0.0     X25
 96 101E33 12N52  0.  1           0.0   0.0   0.0     X26
 97 104E14 15N26  0.  1           0.0   0.0   0.0     X27
 98 104E44 15N20  0.  1           0.0   0.0   0.0     X28
 99  99E38 16N53  0.  1           0.0   0.0   0.0     X29
100 104E23 15N16  0.  1           0.0   0.0   0.0     X30
Format:(i3,i4,a1,i2,i3,a1,i2,I4,2i3,f5.0,3f6.1,5x,a6)
```

/**

Rout.tha

**/

```
  4 routing principles
HHHHH  Lev1
HHHHH  Lev2
HHHHH  Lev3
HHHDD  Lev4
DDDDD  internal traffic
 -1 -1 -1 -1 -1     Lev1
 -2 -1 -1 -1 -1     Lev2
 -2 -2 -1 -1 -1     Lev3
 -2 -2 -2  0  0     Lev4
        0  0  0  0  0
Lev1Lev2Lev3Lev4
```

/**

Traf95.tha

**/

```
70
    0.00   93.65   20.00  397.56   59.84   66.55   52.10   15.69  214.68   13.27
```

17.71	28.16	64.13	11.18	16.28	161.15	6.95	11.53	12.01	101.33
33.68	25.28	11.88	7.92	11.53	66.00	34.03	29.13	47.94	50.40
96.56	27.57	80.34	10.41	23.36	347.67	7.24	1.32	45.83	57.09
10.67	10.63	30.47	224.11	109.82	18.72	111.19	89.96	121.77	64.75
85.18	28.25	23.87	86.04	8.65	78.19	30.43	6.62	181.15	5.85
8.91	25.41	29.22	26.38	136.49	29.68	68.60	139.52	94.05	52.78
91.35	0.00	47.50	4.96	3.03	0.32	0.36	0.05	2.16	0.21
0.21	0.32	0.27	0.05	0.06	0.19	0.00	0.01	0.00	0.43
0.00	0.13	0.10	0.05	0.00	0.10	0.03	0.15	0.19	0.07
0.18	0.08	0.00	0.09	0.08	0.53	0.00	0.00	0.02	0.03
0.06	0.00	0.00	1.04	0.21	0.01	1.15	0.57	0.55	0.50
0.03	0.01	0.07	0.09	0.00	0.24	0.01	0.03	0.13	0.01
0.00	0.01	0.00	0.04	1.12	0.02	0.19	1.40	0.96	0.27
16.83	49.41	0.00	0.42	0.29	0.04	0.03	0.03	0.71	0.00
0.03	0.02	0.14	0.00	0.02	0.12	0.02	0.00	0.00	0.08
0.00	0.00	0.15	0.00	0.02	0.04	0.00	0.00	0.03	0.03
0.03	0.00	0.12	0.00	0.00	0.20	0.00	0.02	0.02	0.00
0.00	0.01	0.00	0.09	0.03	0.08	0.09	0.06	0.11	0.00
0.00	0.01	0.00	0.11	0.02	0.00	0.00	0.00	0.05	0.10
0.00	0.00	0.00	0.00	0.36	0.04	0.25	0.70	0.22	0.00
420.84	5.22	0.41	0.00	228.51	259.21	2.93	1.49	3.96	0.16
0.21	0.24	0.76	0.24	0.16	1.91	0.05	0.03	0.01	1.13
0.34	0.54	0.35	0.11	0.08	0.96	0.13	0.13	0.67	0.29
0.76	0.12	1.67	0.08	0.58	4.42	0.07	0.01	0.32	0.10
0.06	0.01	0.22	1.73	1.13	0.17	1.45	0.71	1.63	0.92
0.87	0.33	0.14	0.86	0.04	0.41	0.24	0.02	1.48	0.03
0.07	0.14	0.17	0.14	0.86	0.26	1.16	1.03	1.06	1.01
85.67	2.77	0.41	215.97	0.00	40.58	0.09	0.05	1.37	0.06
0.12	0.25	0.44	0.38	0.31	0.52	0.09	0.02	0.06	0.65
0.05	0.00	0.02	0.00	0.01	0.16	0.02	0.07	0.12	0.05
0.17	0.19	0.53	0.00	0.02	0.42	0.00	0.00	0.18	0.11
0.08	0.00	0.28	0.63	0.11	0.08	0.15	0.31	0.53	0.35
0.00	0.06	0.05	0.38	0.00	0.05	0.03	0.03	0.14	0.00
0.00	0.00	0.03	0.02	0.47	0.00	0.88	0.24	0.36	0.20
85.07	0.55	0.08	246.77	40.87	0.00	1.48	0.40	0.68	0.00
0.08	0.13	0.16	0.07	0.03	0.18	0.00	0.02	0.00	0.17
0.01	0.00	0.00	0.01	0.00	0.39	0.18	0.02	0.25	0.03
0.01	0.11	0.27	0.01	0.06	0.36	0.05	0.00	0.00	0.04
0.02	0.00	0.00	0.67	0.29	0.15	0.39	0.24	0.51	0.36
0.24	0.01	0.02	0.01	0.05	0.11	0.63	0.00	0.76	0.02
0.00	0.04	0.61	0.01	0.03	0.23	0.07	0.34	0.14	0.00
56.67	1.11	0.08	3.41	0.48	1.58	0.00	54.98	0.80	0.03
0.00	0.07	0.06	0.02	0.00	0.32	0.00	0.01	0.00	0.01
0.05	0.00	0.00	0.02	0.01	0.29	0.00	0.04	0.53	0.03
0.18	0.01	0.55	0.01	0.01	0.28	0.03	0.01	0.00	0.00
0.00	0.00	0.08	0.18	0.52	0.03	0.46	0.08	0.24	0.27
0.16	0.07	0.16	0.00	0.01	0.24	0.00	0.00	0.22	0.00
0.00	0.00	0.20	0.00	0.01	0.07	0.14	0.14	0.27	0.11
17.84	0.64	0.01	1.94	0.11	0.30	52.65	0.00	0.05	0.00
0.02	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.01
0.00	0.08	0.04	0.02	0.00	0.08	0.00	0.10	0.07	0.02
0.04	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
0.00	0.03	0.01	0.01	0.07	0.01	0.02	0.01	0.01	0.05
0.13	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.22	0.42	0.00
272.73	2.08	0.25	4.94	1.39	0.00	0.42	0.02	0.00	104.66
117.27	3.56	4.63	1.21	1.27	16.43	0.63	1.58	0.71	7.36
1.31	1.75	0.69	0.25	0.58	1.12	0.63	0.66	0.25	0.30
0.73	0.14	1.52	0.00	0.43	2.40	0.03	0.00	0.02	0.73
0.00	0.08	0.48	2.50	0.57	0.03	0.41	0.78	1.87	0.18
0.53	0.05	0.07	0.14	0.18	0.37	0.43	0.07	2.01	0.03
0.00	0.19	0.00	0.12	1.25	0.17	0.65	5.17	4.47	0.81
18.13	0.08	0.02	0.29	0.04	0.00	0.01	0.00	105.39	0.00
8.97	0.19	0.24	0.00	0.08	2.12	0.04	0.07	0.08	0.20
0.08	0.23	0.09	0.02	0.13	0.02	0.00	0.00	0.08	0.00
0.07	0.02	0.00	0.00	0.00	0.29	0.00	0.00	0.15	0.01
0.00	0.02	0.00	0.01	0.15	0.00	0.45	0.04	0.06	0.01
0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.02	0.00
0.00	0.00	0.00	0.00	0.09	0.00	0.10	0.29	0.25	0.00
31.06	0.38	0.01	0.41	0.34	0.00	0.01	0.01	109.12	8.29
0.00	2.40	1.09	0.28	0.29	1.51	0.21	0.36	0.08	0.85

0.64	0.16	0.03	0.07	0.06	0.14	0.02	0.07	0.16	0.00
0.07	0.02	0.08	0.04	0.08	0.33	0.04	0.00	0.02	0.05
0.02	0.03	0.00	0.42	0.04	0.00	0.16	0.08	0.27	0.00
0.08	0.01	0.07	0.08	0.00	0.00	0.05	0.00	0.11	0.00
0.00	0.04	0.00	0.01	0.12	0.00	0.13	0.20	0.26	0.24
33.89	0.91	0.02	0.35	0.36	0.00	0.02	0.06	4.77	0.53
2.21	0.00	100.50	16.82	19.51	1.75	0.13	0.68	0.06	0.89
0.14	0.34	0.13	0.05	0.09	0.19	0.00	0.00	0.08	0.00
0.10	0.02	0.40	0.00	0.00	0.26	0.00	0.00	0.00	0.00
0.06	0.01	0.00	0.26	0.07	0.03	0.00	0.12	0.16	0.03
0.07	0.04	0.02	0.11	0.00	0.01	0.01	0.00	0.27	0.00
0.00	0.10	0.00	0.00	0.03	0.00	0.11	0.40	0.06	0.11
74.10	0.24	0.00	1.83	0.06	0.00	0.07	0.07	5.42	0.19
0.95	103.44	0.00	43.63	50.61	3.95	0.24	0.76	0.33	1.95
0.86	0.38	0.39	0.49	1.73	0.21	0.00	0.03	0.00	0.27
0.10	0.00	0.42	0.09	0.00	0.82	0.04	0.00	0.05	0.27
0.00	0.07	0.07	0.63	0.13	0.07	0.46	0.12	0.23	0.09
0.22	0.13	0.13	0.44	0.00	0.06	0.03	0.00	0.36	0.04
0.00	0.08	0.00	0.03	0.14	0.00	0.14	0.61	0.71	0.46
12.39	0.14	0.02	0.33	0.26	0.00	0.02	0.03	1.93	0.09
0.27	17.26	43.51	0.00	8.45	0.35	0.05	0.07	0.02	0.15
0.06	0.11	0.08	0.03	0.17	0.08	0.00	0.01	0.00	0.00
0.00	0.02	0.21	0.00	0.00	0.16	0.00	0.01	0.01	0.00
0.00	0.00	0.00	0.29	0.12	0.03	0.02	0.09	0.10	0.01
0.40	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00
0.00	0.03	0.00	0.00	0.06	0.00	0.00	0.06	0.03	0.07
19.47	0.02	0.03	0.42	0.78	0.00	0.06	0.00	1.28	0.00
0.22	19.75	49.79	8.33	0.00	1.67	0.35	0.99	0.21	0.19
0.98	0.17	0.03	0.04	0.21	0.14	0.00	0.02	0.00	0.00
0.00	0.00	0.15	0.07	0.00	0.16	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.14	0.03	0.00	0.00	0.00	0.37	0.03
0.08	0.03	0.00	0.03	0.00	0.04	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01	0.00	0.24
196.43	0.64	0.18	2.13	0.31	0.00	0.06	0.11	14.80	1.59
0.70	1.00	3.11	0.44	1.39	0.00	65.96	75.90	69.38	16.07
2.88	4.77	1.81	0.71	0.93	0.97	0.40	0.14	0.21	0.49
0.32	0.13	1.48	0.03	0.00	2.20	0.02	0.01	0.44	0.42
0.09	0.08	0.30	1.39	1.04	0.17	0.87	0.51	0.84	0.28
0.34	0.15	0.00	0.02	0.00	0.58	0.02	0.06	0.77	0.08
0.00	0.03	0.00	0.05	0.78	0.19	0.52	1.14	0.43	0.31
16.57	0.05	0.01	0.08	0.03	0.00	0.00	0.03	0.59	0.08
0.39	0.35	0.45	0.02	0.16	62.53	0.00	6.03	5.52	0.40
0.06	0.27	0.15	0.03	0.06	0.11	0.01	0.00	0.11	0.03
0.02	0.04	0.08	0.00	0.00	0.18	0.00	0.00	0.00	0.01
0.00	0.00	0.02	0.20	0.03	0.02	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.04	0.00
0.00	0.00	0.05	0.00	0.02	0.00	0.02	0.01	0.04	0.00
21.88	0.03	0.08	0.22	0.03	0.00	0.04	0.00	1.22	0.07
0.26	0.43	0.63	0.10	1.25	71.20	5.97	0.00	6.28	0.37
0.24	0.15	0.09	0.03	0.11	0.12	0.02	0.00	0.04	0.03
0.09	0.01	0.13	0.01	0.00	0.11	0.01	0.00	0.00	0.00
0.02	0.00	0.05	0.21	0.02	0.01	0.00	0.05	0.17	0.32
0.00	0.03	0.01	0.04	0.00	0.04	0.02	0.00	0.03	0.00
0.00	0.01	0.00	0.01	0.02	0.02	0.02	0.12	0.03	0.00
17.24	0.02	0.00	0.24	0.04	0.00	0.03	0.00	1.26	0.13
0.09	0.28	0.43	0.03	0.92	66.28	5.56	6.40	0.00	0.76
0.10	0.13	0.21	0.17	0.20	0.06	0.00	0.00	0.00	0.00
0.04	0.00	0.13	0.00	0.00	0.06	0.00	0.00	0.14	0.00
0.01	0.00	0.04	0.12	0.04	0.00	0.10	0.00	0.04	0.00
0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
0.00	0.00	0.00	0.00	0.01	0.00	0.06	0.05	0.00	0.00
120.13	0.20	0.38	1.56	0.52	0.00	0.02	0.00	6.17	0.57
0.86	0.40	1.28	0.31	0.08	16.16	0.52	0.40	0.58	0.00
120.10	133.88	82.28	40.86	48.51	0.68	0.02	0.14	0.07	0.01
0.25	0.03	1.19	0.05	0.16	2.51	0.02	0.00	0.30	0.10
0.04	0.01	0.09	0.47	0.18	0.04	0.08	0.30	1.09	0.23
0.07	0.05	0.14	0.10	0.07	0.12	0.00	0.00	0.71	0.03
0.08	0.17	0.00	0.00	0.19	0.53	0.07	0.48	0.24	0.31
48.91	0.00	0.05	0.18	0.00	0.00	0.00	0.00	0.73	0.04
0.31	0.17	0.29	0.13	0.09	4.15	0.08	0.07	0.02	116.63
0.00	35.93	22.08	10.97	13.02	0.10	0.12	0.03	0.00	0.00

0.07	0.00	0.21	0.00	0.10	0.80	0.00	0.00	0.00	0.16
0.04	0.00	0.01	0.00	0.03	0.00	0.02	0.10	0.00	0.18
0.06	0.00	0.02	0.00	0.00	0.10	0.00	0.12	0.12	0.00
0.00	0.17	0.00	0.00	0.09	0.00	0.00	0.16	0.22	0.04
39.86	0.29	0.02	0.44	0.00	0.00	0.00	0.22	2.29	0.42
0.30	0.33	0.57	0.11	0.90	7.51	0.37	0.04	0.08	127.76
35.31	0.00	24.19	12.01	14.26	0.26	0.07	0.15	0.31	0.06
0.17	0.10	1.23	0.00	0.02	0.19	0.02	0.00	0.04	0.06
0.01	0.00	0.10	0.19	0.20	0.00	0.30	0.03	0.03	0.08
0.00	0.08	0.00	0.11	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.09	0.14	0.00	0.76	0.00	0.03	0.31	0.24	0.06
21.40	0.00	0.00	0.17	0.00	0.00	0.04	0.00	1.48	0.06
0.01	0.11	0.70	0.01	0.30	2.14	0.20	0.05	0.31	8.43
22.23	24.78	0.00	7.56	8.98	0.04	0.03	0.01	0.02	0.02
0.10	0.05	0.03	0.00	0.00	0.36	0.00	0.00	0.04	0.00
0.08	0.00	0.00	0.08	0.00	0.12	0.05	0.01	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00
0.00	0.00	0.00	0.00	0.18	0.00	0.14	0.02	0.14	0.00
16.67	0.07	0.00	0.16	0.07	0.00	0.00	0.00	0.44	0.07
0.04	0.02	0.70	0.06	0.07	0.97	0.07	0.05	0.11	37.86
10.46	11.66	7.17	0.00	4.23	0.12	0.03	0.00	0.07	0.04
0.03	0.01	0.07	0.01	0.00	0.18	0.00	0.00	0.00	0.02
0.00	0.00	0.03	0.08	0.00	0.00	0.06	0.00	0.04	0.10
0.02	0.00	0.00	0.06	0.02	0.00	0.00	0.00	0.07	0.00
0.00	0.01	0.00	0.00	0.05	0.02	0.00	0.00	0.07	0.04
19.36	0.04	0.02	0.02	0.37	0.01	0.04	0.00	0.87	0.00
0.01	0.15	2.97	0.19	0.30	1.19	0.12	0.15	0.04	45.75
12.64	14.09	8.66	4.30	0.00	0.00	0.01	0.00	0.00	0.00
0.11	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.02	0.01
0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.14	0.00
0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.04	0.00	0.00
77.00	0.12	0.11	1.04	0.10	0.04	0.32	0.00	0.56	0.01
0.08	0.12	0.14	0.00	0.00	0.62	0.00	0.04	0.01	0.28
0.05	0.21	0.06	0.02	0.06	0.00	55.84	61.23	81.86	68.25
2.60	2.21	2.99	0.07	0.20	5.12	0.12	0.02	0.39	0.55
0.26	0.09	1.06	0.83	0.19	0.03	0.24	0.25	0.26	0.07
0.10	0.01	0.00	0.10	0.00	0.11	0.03	0.03	0.39	0.02
0.00	0.01	0.04	0.06	0.20	0.08	0.26	0.51	0.69	0.34
39.83	0.05	0.02	0.10	0.02	0.10	0.07	0.00	0.33	0.03
0.02	0.23	0.01	0.00	0.00	0.58	0.00	0.00	0.06	0.07
0.15	0.13	0.00	0.00	0.02	52.82	0.00	22.41	29.96	24.98
1.24	0.52	0.61	0.03	0.14	2.75	0.12	0.00	0.24	0.63
0.26	0.09	1.20	0.19	0.10	0.00	0.00	0.00	0.14	0.00
0.05	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.18	0.00
0.00	0.01	0.06	0.01	0.33	0.02	0.16	0.13	0.24	0.22
32.88	0.04	0.05	0.17	0.01	0.07	0.13	0.04	0.41	0.01
0.01	0.08	0.02	0.00	0.10	0.16	0.00	0.00	0.00	0.14
0.16	0.00	0.01	0.04	0.00	60.15	23.27	0.00	34.12	28.45
1.21	0.14	0.75	0.02	0.45	2.93	0.01	0.03	0.24	1.08
0.42	0.07	2.08	0.06	0.17	0.00	0.03	0.00	0.06	0.00
0.12	0.08	0.00	0.08	0.00	0.17	0.00	0.00	0.27	0.00
0.00	0.01	0.01	0.00	0.05	0.02	0.18	0.41	0.20	0.14
67.69	0.00	0.06	0.80	0.16	0.19	0.04	0.00	0.20	0.53
0.21	0.03	0.09	0.01	0.00	0.52	0.05	0.01	0.09	0.08
0.02	0.00	0.05	0.06	0.00	74.75	28.93	31.72	0.00	35.36
9.69	1.44	0.74	0.73	0.30	3.55	0.17	0.02	0.17	0.99
0.12	0.31	0.25	0.28	0.05	0.04	0.54	0.37	0.44	0.01
0.00	0.02	0.01	0.08	0.00	0.00	0.14	0.00	0.28	0.00
0.00	0.00	0.02	0.03	0.71	0.10	0.17	0.36	0.47	0.66
49.96	0.08	0.01	0.76	0.01	0.04	0.11	0.00	0.08	0.00
0.01	0.16	0.03	0.08	0.00	0.19	0.08	0.02	0.02	0.08
0.05	0.01	0.05	0.00	0.00	65.62	25.39	27.84	37.23	0.00
2.76	0.29	0.85	0.01	0.19	4.24	0.16	0.06	0.47	1.40
0.09	0.18	0.34	0.31	0.16	0.00	0.55	0.05	0.14	0.11
0.01	0.00	0.12	0.03	0.05	0.13	0.00	0.00	0.07	0.00
0.00	0.00	0.00	0.00	0.22	0.14	0.00	0.09	0.24	0.45
91.13	0.10	0.05	0.60	0.19	0.02	0.00	0.00	0.92	0.02
0.07	0.07	0.15	0.00	0.00	0.35	0.01	0.11	0.02	0.14
0.02	0.13	0.02	0.00	0.23	3.31	0.95	0.96	7.11	1.84
0.00	64.21	89.45	20.32	41.48	3.48	0.12	0.00	0.45	0.59

0.13	0.17	0.53	0.49	0.35	0.05	0.34	0.48	0.24	0.00
0.40	0.11	0.04	0.10	0.02	0.25	0.01	0.00	0.20	0.00
0.01	0.02	0.00	0.07	1.16	0.09	0.24	0.76	1.71	1.90
31.19	0.14	0.03	0.31	0.00	0.01	0.00	0.00	0.46	0.00
0.00	0.00	0.06	0.02	0.00	0.17	0.00	0.00	0.05	0.05
0.01	0.05	0.00	0.00	0.00	2.56	0.40	0.40	1.41	0.54
61.50	0.00	29.18	6.63	13.53	0.99	0.00	0.01	0.03	0.25
0.01	0.01	0.17	0.34	0.15	0.01	0.07	0.09	0.11	0.01
0.06	0.03	0.00	0.05	0.00	0.00	0.03	0.01	0.06	0.00
0.00	0.15	0.00	0.05	0.37	0.07	0.00	0.25	0.65	0.04
84.43	0.24	0.13	0.35	0.15	0.03	0.56	0.01	1.12	0.04
0.34	0.01	0.18	0.00	0.00	1.51	0.29	0.06	0.10	0.57
0.33	0.45	0.12	0.08	0.00	4.75	1.12	0.82	0.92	0.14
82.65	28.15	0.00	8.91	18.19	3.26	0.08	0.04	0.50	0.49
0.33	0.00	0.33	0.42	0.52	0.03	0.27	0.17	0.26	0.30
0.08	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.56	0.16
0.01	0.37	0.00	0.00	1.16	0.05	0.10	1.28	2.76	0.51
12.35	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.04	0.00
0.00	0.04	0.00	0.01	0.00	0.02	0.01	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.00	0.20	0.02	0.01	0.18	0.07
19.94	6.79	9.46	0.00	4.39	0.22	0.01	0.00	0.01	0.03
0.00	0.00	0.00	0.02	0.00	0.00	0.05	0.00	0.01	0.04
0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
0.00	0.00	0.02	0.00	0.00	0.07	0.23	0.04	0.09	0.40
31.64	0.31	0.00	0.28	0.17	0.00	0.00	0.00	0.42	0.00
0.00	0.00	0.07	0.09	0.00	0.15	0.00	0.00	0.00	0.05
0.09	0.00	0.00	0.00	0.00	0.37	0.00	0.03	0.83	0.13
37.27	12.69	17.68	4.02	0.00	0.16	0.00	0.00	0.08	0.10
0.00	0.14	0.15	0.26	0.01	0.08	0.27	0.07	0.34	0.00
0.10	0.00	0.00	0.20	0.00	0.02	0.00	0.00	0.12	0.04
0.00	0.00	0.00	0.00	0.97	0.14	0.67	0.43	0.93	1.81
502.06	1.30	0.37	5.97	0.11	0.73	0.26	0.11	4.27	0.23
0.11	0.07	1.45	0.04	0.06	3.45	0.13	0.07	0.02	1.89
0.87	0.13	0.84	0.22	0.14	6.58	2.53	2.65	3.75	4.95
4.35	0.75	2.59	0.37	1.84	0.00	102.26	31.65	16.32	19.09
2.60	3.36	6.33	2.32	1.63	0.44	0.62	1.05	1.30	0.75
0.72	0.40	0.27	0.95	0.00	0.98	0.11	0.24	2.89	0.06
0.04	0.34	0.09	0.56	1.09	0.39	0.79	1.81	1.69	0.87
13.97	0.00	0.03	0.10	0.07	0.00	0.06	0.00	0.12	0.02
0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.03	0.01	0.04
0.00	0.02	0.00	0.00	0.00	0.24	0.11	0.33	0.39	0.02
0.10	0.03	0.18	0.02	0.19	101.43	0.00	1.02	0.39	0.69
0.12	0.10	0.04	0.10	0.04	0.00	0.00	0.07	0.20	0.01
0.12	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.37	0.00
0.00	0.00	0.00	0.03	0.00	0.00	0.04	0.14	0.07	0.21
2.34	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.00
0.00	0.00	0.00	0.01	0.00	0.06	0.01	0.01	0.00	0.16
0.00	0.02	0.00	0.01	0.04	32.43	1.05	0.00	0.11	0.21
0.00	0.02	0.09	0.00	0.00	0.00	0.00	0.01	0.02	0.10
0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
57.07	0.06	0.02	0.77	1.44	0.00	0.06	0.00	0.09	0.03
0.06	0.04	0.02	0.00	0.06	0.18	0.00	0.02	0.00	0.17
0.03	0.00	0.01	0.02	0.00	0.57	0.17	0.43	0.19	0.35
0.45	0.21	0.61	0.02	0.24	14.09	0.60	0.08	0.00	89.51
18.29	23.88	49.21	0.24	0.07	0.00	0.00	0.01	0.09	0.31
0.00	0.00	0.06	0.01	0.00	0.32	0.06	0.01	0.25	0.04
0.00	0.06	0.16	0.12	0.13	0.02	0.00	0.30	0.34	0.28
64.74	0.00	0.04	0.62	0.19	0.00	0.02	0.00	0.31	0.06
0.00	0.00	0.01	0.00	0.00	0.46	0.05	0.01	0.14	0.48
0.16	0.51	0.01	0.01	0.08	0.92	0.61	1.03	0.48	1.03
0.53	0.17	0.53	0.04	0.00	13.05	0.68	0.09	92.03	0.00
21.92	28.62	58.98	0.27	0.11	0.01	0.11	0.00	0.28	0.10
0.14	0.01	0.16	0.09	0.01	0.06	0.00	0.00	0.22	0.00
0.09	0.00	0.00	0.03	0.39	0.05	0.18	0.36	0.08	0.56
10.91	0.00	0.00	0.13	0.04	0.00	0.06	0.00	0.08	0.03
0.00	0.00	0.01	0.00	0.00	0.07	0.03	0.00	0.00	0.06
0.07	0.03	0.07	0.01	0.01	0.39	0.44	0.68	0.26	0.17
0.18	0.02	0.31	0.00	0.03	3.07	0.07	0.00	18.35	21.39
0.00	5.71	11.76	0.08	0.01	0.00	0.00	0.05	0.01	0.08

0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.03	0.05
0.00	0.00	0.00	0.00	0.22	0.00	0.01	0.02	0.16	0.00
19.07	0.00	0.01	0.27	0.06	0.00	0.02	0.00	0.04	0.02
0.00	0.00	0.01	0.00	0.00	0.05	0.03	0.00	0.04	0.14
0.00	0.10	0.00	0.00	0.00	0.24	0.05	0.23	0.26	0.09
0.31	0.08	0.05	0.00	0.07	4.17	0.14	0.01	22.40	26.11
5.34	0.00	14.36	0.12	0.07	0.00	0.02	0.15	0.01	0.00
0.01	0.02	0.02	0.00	0.00	0.08	0.02	0.00	0.14	0.02
0.00	0.00	0.00	0.21	0.12	0.00	0.02	0.02	0.07	0.03
36.78	0.00	0.16	0.23	0.05	0.12	0.15	0.00	0.34	0.00
0.13	0.00	0.13	0.01	0.09	0.40	0.04	0.02	0.00	0.02
0.11	0.28	0.00	0.02	0.00	1.77	0.86	1.84	0.37	0.28
0.45	0.05	0.51	0.00	0.01	5.65	0.12	0.04	49.20	57.35
11.72	15.30	0.00	0.07	0.05	0.02	0.00	0.27	0.08	0.03
0.09	0.12	0.00	0.00	0.00	0.04	0.00	0.00	0.09	0.00
0.00	0.03	0.11	0.06	0.19	0.00	0.21	0.18	0.24	0.13
243.87	0.46	0.21	2.17	0.67	0.38	0.18	0.17	1.45	0.41
0.17	0.21	0.22	0.11	0.17	0.79	0.06	0.14	0.15	0.67
0.57	0.15	0.08	0.08	0.03	0.75	0.05	0.01	0.43	0.15
0.31	0.79	0.27	0.00	0.02	2.78	0.01	0.00	0.33	0.05
0.03	0.11	0.04	0.00	237.95	37.05	222.44	3.68	12.37	2.15
0.89	0.20	0.12	0.34	0.08	0.88	0.42	0.05	1.86	0.03
0.02	0.08	0.02	0.48	0.73	0.19	4.39	0.74	0.55	0.38
115.01	0.12	0.01	0.65	0.04	0.04	0.13	0.12	0.81	0.01
0.03	0.08	0.16	0.11	0.00	0.82	0.05	0.00	0.01	0.19
0.10	0.00	0.02	0.00	0.00	0.17	0.07	0.06	0.10	0.03
0.24	0.04	0.40	0.02	0.17	0.82	0.05	0.00	0.00	0.01
0.00	0.03	0.00	239.75	0.00	16.94	101.73	0.99	2.56	1.68
1.03	0.22	0.10	0.46	0.00	0.45	0.06	0.00	1.20	0.07
0.08	0.13	0.34	0.05	1.06	0.04	0.43	0.31	0.24	0.23
21.24	0.19	0.02	0.28	0.14	0.11	0.04	0.00	0.08	0.00
0.01	0.00	0.02	0.04	0.00	0.02	0.00	0.01	0.00	0.08
0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.04	0.00	0.02
0.01	0.01	0.00	0.04	0.02	0.09	0.01	0.00	0.00	0.01
0.04	0.00	0.02	36.74	16.67	0.00	15.59	0.87	2.05	0.52
0.13	0.26	0.06	0.05	0.00	0.01	0.02	0.00	0.20	0.00
0.00	0.01	0.00	0.00	0.14	0.00	0.06	0.12	0.06	0.13
140.33	0.61	0.03	1.16	0.15	0.42	0.27	0.02	0.75	0.02
0.04	0.00	0.29	0.02	0.06	0.52	0.01	0.03	0.17	0.16
0.00	0.00	0.18	0.00	0.03	0.14	0.00	0.03	0.14	0.27
0.47	0.04	0.24	0.26	0.00	0.62	0.05	0.00	0.13	0.18
0.00	0.06	0.01	212.17	96.30	14.99	0.00	2.15	8.68	0.30
0.34	0.17	0.04	0.48	0.22	0.42	0.15	0.00	0.73	0.00
0.00	0.21	0.00	0.02	0.14	0.02	3.48	0.90	0.54	1.66
95.54	0.55	0.09	0.83	0.09	0.00	0.01	0.04	0.80	0.10
0.01	0.00	0.08	0.03	0.03	0.37	0.02	0.02	0.01	0.28
0.01	0.00	0.04	0.01	0.08	0.13	0.00	0.03	0.00	0.13
0.32	0.08	0.34	0.01	0.00	0.76	0.02	0.00	0.36	0.21
0.00	0.00	0.06	4.28	1.46	0.96	2.48	0.00	137.45	64.32
0.98	0.63	0.17	0.69	0.14	0.38	0.16	0.04	0.93	0.03
0.00	0.09	0.02	0.11	0.12	0.12	0.31	0.09	0.65	0.26
144.91	0.31	0.01	2.16	0.05	0.43	0.15	0.07	0.83	0.06
0.05	0.03	0.21	0.05	0.04	0.63	0.06	0.06	0.04	0.56
0.06	0.03	0.03	0.09	0.03	0.20	0.07	0.05	0.18	0.11
0.37	0.03	0.08	0.01	0.16	0.43	0.11	0.07	0.06	0.17
0.01	0.02	0.14	11.00	2.61	1.44	8.41	143.56	0.00	165.79
0.52	0.28	0.15	0.54	0.04	1.10	0.03	0.06	0.73	0.01
0.10	0.09	0.01	0.13	0.25	0.12	0.98	0.71	0.58	0.15
71.75	0.38	0.01	1.35	0.00	0.22	0.28	0.01	0.36	0.06
0.05	0.01	0.19	0.02	0.00	0.43	0.00	0.01	0.00	0.01
0.41	0.01	0.01	0.00	0.39	0.08	0.05	0.22	0.00	0.34
0.21	0.01	0.50	0.02	0.03	0.67	0.01	0.00	0.14	0.06
0.05	0.00	0.05	2.90	1.73	0.75	2.73	65.40	161.40	0.00
0.68	1.20	0.30	0.64	0.10	0.60	0.17	0.00	0.87	0.26
0.06	0.16	0.20	0.12	0.20	0.11	0.37	0.19	0.29	0.02
112.23	0.00	0.10	0.94	0.00	0.00	0.04	0.14	0.41	0.00
0.01	0.00	0.09	0.04	0.00	0.73	0.01	0.02	0.00	0.40
0.05	0.00	0.08	0.07	0.00	0.25	0.02	0.24	0.15	0.02
0.01	0.03	0.22	0.00	0.00	0.88	0.00	0.00	0.02	0.04
0.07	0.01	0.15	1.90	1.11	0.13	0.42	0.75	0.77	0.36
0.00	111.41	90.16	4.19	0.60	9.21	1.70	0.43	8.27	0.65

0.65	0.58	0.53	0.74	0.04	0.00	0.05	0.43	0.04	0.00
34.92	0.00	0.03	0.43	0.04	0.00	0.01	0.00	0.20	0.00
0.02	0.00	0.00	0.03	0.00	0.14	0.00	0.01	0.00	0.11
0.00	0.00	0.00	0.03	0.02	0.05	0.02	0.01	0.01	0.01
0.53	0.08	0.00	0.02	0.11	0.20	0.01	0.00	0.00	0.00
0.01	0.00	0.00	0.51	0.46	0.58	0.09	0.78	0.26	1.19
109.68	0.00	25.20	0.84	0.21	1.14	0.59	0.01	1.76	0.14
0.14	0.12	0.11	0.10	0.10	0.05	0.00	0.06	0.05	0.00
30.20	0.23	0.00	0.03	0.00	0.00	0.05	0.00	0.07	0.00
0.01	0.00	0.02	0.00	0.00	0.07	0.00	0.01	0.00	0.02
0.00	0.00	0.00	0.00	0.00	0.07	0.01	0.00	0.01	0.02
0.08	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.12	0.00
0.02	0.00	0.01	0.22	0.07	0.10	0.25	0.25	0.31	0.29
88.92	25.25	0.00	1.87	0.37	0.66	0.22	0.05	0.97	0.19
0.03	0.00	0.02	0.18	0.00	0.00	0.00	0.05	0.03	0.08
114.28	0.01	0.00	0.62	0.00	0.00	0.35	0.00	0.29	0.00
0.13	0.03	0.15	0.00	0.32	0.14	0.00	0.00	0.04	0.05
0.00	0.02	0.01	0.01	0.04	0.09	0.07	0.04	0.21	0.12
0.17	0.04	0.03	0.00	0.00	0.96	0.03	0.00	0.00	0.09
0.00	0.00	0.00	0.84	0.77	0.11	0.46	0.16	0.34	0.49
3.89	0.90	1.56	0.00	72.45	2.78	2.79	1.06	8.53	0.47
0.25	0.45	0.54	0.19	0.01	0.00	0.18	0.09	0.01	0.02
17.29	0.00	0.00	0.09	0.02	0.00	0.00	0.00	0.02	0.03
0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.07	0.00
0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.01	0.00	0.00	0.13	0.10	0.00	0.00	0.00	0.02
0.00	0.00	0.10	0.10	0.00	0.03	0.00	0.02	0.24	0.19
0.97	0.18	0.60	69.48	0.00	0.51	0.30	0.32	0.92	0.11
0.04	0.07	0.01	0.04	0.17	0.00	0.00	0.00	0.00	0.00
95.46	0.88	0.04	0.39	0.08	0.00	0.21	0.02	0.84	0.02
0.06	0.02	0.01	0.00	0.11	0.17	0.00	0.02	0.04	0.05
0.03	0.00	0.00	0.01	0.00	0.07	0.23	0.16	0.07	0.11
0.29	0.01	0.20	0.03	0.02	0.48	0.05	0.03	0.04	0.23
0.00	0.15	0.00	1.06	0.54	0.04	0.25	0.77	0.38	0.44
7.93	1.50	0.58	1.98	0.66	0.00	151.34	32.11	14.26	0.53
0.93	0.88	0.88	0.81	0.17	0.00	0.17	0.02	0.12	0.00
48.23	0.03	0.00	0.33	0.00	0.00	0.01	0.00	0.04	0.00
0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.02	0.16
0.00	0.00	0.02	0.00	0.00	0.05	0.01	0.04	0.00	0.00
0.06	0.01	0.03	0.01	0.00	0.15	0.02	0.00	0.00	0.07
0.00	0.00	0.00	0.67	0.10	0.00	0.15	0.21	0.14	0.22
3.28	0.07	0.33	3.67	0.39	150.38	0.00	19.46	6.79	1.14
0.87	0.83	0.45	0.29	0.02	0.00	0.00	0.00	0.05	0.00
8.46	0.00	0.00	0.01	0.08	0.00	0.00	0.00	0.01	0.00
0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
0.00	0.00	0.08	0.00	0.00	0.04	0.00	0.00	0.00	0.06
0.00	0.00	0.00	0.05	0.05	0.07	0.00	0.03	0.05	0.06
0.64	0.09	0.05	1.42	0.27	32.42	19.78	0.00	0.65	0.11
0.05	0.05	0.20	0.24	0.06	0.01	0.00	0.00	0.00	0.00
249.27	0.04	0.03	1.84	0.22	0.19	0.16	0.10	1.15	0.03
0.02	0.03	0.48	0.09	0.07	1.00	0.03	0.02	0.06	0.48
0.07	0.09	0.02	0.05	0.00	0.51	0.04	0.26	0.37	0.26
0.28	0.09	0.85	0.02	0.00	4.11	0.07	0.00	0.73	0.35
0.05	0.11	0.08	2.42	2.11	0.57	0.39	1.38	1.54	1.29
10.49	1.71	1.57	9.19	1.00	12.70	8.21	0.80	0.00	87.49
59.93	9.79	10.24	6.71	0.19	0.11	0.11	0.21	0.18	0.11
12.60	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.00
0.00	0.00	0.01	0.00	0.00	0.55	0.00	0.00	0.06	0.01
0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.09
0.00	0.00	0.00	0.23	0.22	0.22	0.00	0.17	0.10	0.37
0.73	0.11	0.05	0.35	0.06	0.45	1.26	0.17	86.38	0.00
3.53	0.11	0.64	0.43	0.00	0.00	0.00	0.03	0.00	0.00
16.68	0.04	0.00	0.10	0.00	0.00	0.04	0.00	0.02	0.00
0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.13
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.01	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
0.00	0.00	0.02	0.18	0.00	0.01	0.19	0.07	0.04	0.08
1.00	0.07	0.06	0.22	0.32	1.46	1.30	0.06	54.32	3.24
0.00	0.40	0.43	0.56	0.05	0.00	0.00	0.00	0.01	0.00

34.10	0.01	0.00	0.30	0.00	0.00	0.01	0.00	0.19	0.00
0.01	0.00	0.00	0.00	0.00	0.09	0.00	0.01	0.00	0.02
0.00	0.00	0.00	0.00	0.15	0.01	0.02	0.00	0.00	0.01
0.02	0.02	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.10
0.00	0.00	0.01	0.14	0.08	0.01	0.05	0.04	0.08	0.01
0.69	0.09	0.03	0.54	0.10	0.89	0.37	0.13	10.81	0.43
0.28	0.00	70.32	74.66	0.00	0.16	0.01	0.00	0.01	0.00
34.44	0.00	0.00	0.01	0.61	0.00	0.03	0.00	0.08	0.00
0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.12
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
0.00	0.03	0.10	0.00	0.00	0.13	0.00	0.00	0.00	0.00
0.00	0.02	0.00	0.04	0.52	0.02	0.08	0.25	0.05	0.19
1.29	0.07	0.11	0.44	0.33	1.92	1.31	0.09	11.73	0.67
0.47	69.91	0.00	80.95	0.02	0.00	0.00	0.00	0.02	0.25
34.92	0.00	0.00	0.13	0.00	0.00	0.11	0.00	0.01	0.00
0.00	0.01	0.10	0.00	0.00	0.26	0.00	0.00	0.03	0.03
0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.06
0.06	0.03	0.26	0.00	0.00	0.81	0.02	0.00	0.12	0.03
0.00	0.08	0.13	0.86	0.17	0.02	0.07	0.59	0.38	0.14
0.52	0.13	0.12	0.35	0.08	0.72	0.50	0.27	9.47	0.31
0.63	73.59	80.27	0.00	0.00	0.00	0.03	0.08	0.01	0.06
127.62	0.28	0.49	1.77	0.11	0.00	0.20	0.02	1.22	0.02
0.05	0.00	0.09	0.00	0.00	0.38	0.07	0.10	0.00	0.45
0.18	0.36	0.02	0.03	0.04	0.60	0.17	0.16	0.81	0.05
0.98	0.57	0.81	0.03	0.46	0.59	0.01	0.01	0.37	0.19
0.03	0.00	0.08	0.84	0.48	0.01	0.38	0.24	0.31	0.29
0.10	0.00	0.00	0.00	0.01	0.08	0.00	0.00	0.13	0.00
0.00	0.08	0.00	0.05	0.00	41.42	133.37	5.10	3.08	1.82
29.35	0.11	0.01	0.16	0.00	0.00	0.07	0.00	0.47	0.01
0.00	0.05	0.08	0.00	0.00	0.09	0.02	0.06	0.00	0.00
0.04	0.00	0.01	0.03	0.03	0.04	0.00	0.00	0.30	0.02
0.47	0.12	0.09	0.00	0.11	0.18	0.10	0.00	0.00	0.10
0.00	0.00	0.00	0.10	0.06	0.05	0.19	0.00	0.07	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00
0.00	0.03	0.00	0.01	39.68	0.00	25.88	0.81	0.95	1.65
72.49	0.13	0.03	0.76	0.03	0.06	0.14	0.03	0.95	0.06
0.01	0.05	0.04	0.00	0.00	0.38	0.00	0.07	0.08	0.30
0.13	0.00	0.00	0.00	0.00	0.44	0.05	0.11	0.13	0.10
0.34	0.00	0.23	0.25	0.49	0.27	0.03	0.00	0.00	0.03
0.00	0.08	0.00	3.95	0.59	0.21	2.82	0.53	1.18	0.06
0.06	0.06	0.00	0.12	0.02	0.27	0.00	0.00	0.13	0.00
0.00	0.04	0.00	0.09	132.84	26.90	0.00	0.56	1.07	1.30
137.79	1.75	0.60	1.24	0.30	0.00	0.07	0.00	5.14	0.23
0.13	0.05	0.54	0.04	0.04	1.42	0.02	0.04	0.10	0.47
0.00	0.34	0.06	0.06	0.05	0.35	0.09	0.34	0.56	0.04
0.36	0.07	0.84	0.06	0.41	0.99	0.01	0.00	0.06	0.11
0.10	0.01	0.54	0.84	0.28	0.07	0.56	0.17	1.12	0.18
0.17	0.03	0.01	0.21	0.00	0.19	0.02	0.00	0.20	0.02
0.00	0.02	0.19	0.00	5.51	0.43	0.41	0.00	173.03	74.73
93.01	0.89	0.08	1.41	0.38	0.00	0.25	0.12	2.49	0.10
0.10	0.09	0.13	0.01	0.09	0.68	0.04	0.04	0.04	0.86
0.00	0.03	0.00	0.08	0.10	0.88	0.39	0.45	0.31	0.25
1.96	0.41	1.67	0.28	0.81	1.59	0.24	0.00	0.12	0.28
0.08	0.00	0.01	0.60	0.83	0.05	0.89	0.33	0.59	0.14
0.19	0.00	0.05	0.01	0.04	0.09	0.07	0.00	0.35	0.00
0.00	0.10	0.00	0.04	3.60	0.45	0.50	177.14	0.00	68.54
65.35	0.30	0.12	0.53	0.00	0.00	0.04	0.00	0.97	0.00
0.01	0.18	0.00	0.17	0.00	0.34	0.00	0.05	0.00	0.08
0.17	0.00	0.00	0.00	0.00	0.45	0.13	0.16	1.20	0.15
2.06	0.15	1.87	0.81	1.76	1.64	0.09	0.00	0.20	0.15
0.00	0.03	0.10	0.52	0.06	0.07	0.34	0.00	1.22	0.07
0.16	0.18	0.00	0.10	0.00	0.12	0.09	0.00	0.12	0.00
0.00	0.00	0.76	0.15	0.64	1.19	1.40	70.26	62.95	0.00

/**
Transys.tha
**/

```
  7        TRANSMISSION SYSTEMS   (DIGITAL)
DL4   480     30.   7610.   4570.     0.   2  1  1
```

```
DL5   960     30.  11090.   6300.     0.   2  1  1
DL61 1920     30.  14780.   6910.     0.   2  1  1
DL62 3840     30.  22810.   8660.     0.   2  1  1
DL63 5760     30.  30540.  10400.     0.   2  1  1
DL7   960      0.   4130.      0.   531.2  2  2  1
*    1920          15980.      0.   153.6  2  2  1
  1
  7  1  2  3  4  5  6  7
  2                     lists of inter-exchange, or exchange-subscriber,
systems
  2                    table of inter-exchange
  1  1
  1  1
  7 systems in table 1 (between exchanges)
  1  2  3  4  5  6  7
  7 systems in table 2 (between NODES AND exchanges)
  1  2  3  4  5  6  7
```

APPENDIX C. INPUT DATA FILES GSM NETWORK

The following lines of text are the actual data input files for the GSM network. All data is real data provided by Siemens Indonesia [2].

/**
Build.tha
**/

```
  3 conversion tables subs. to floor space
 20000.   0.1   5000. 1.     0.   275.  anal
 50000.   195. 10000. 1.     0.    65.  dig
  2000.     2.   128. 1.     0.     2.  RSU
  1 new buildings
  3000.     0.
  4 extensions
   300. 12000.
   500. 18500.
   700. 25000.
   900. 31000.
AnlgDgtlRSU
```

/**
Cosw.tha
**/

```
   1  1  switching tables
 3.462    3.462
Dgtl
```

/**
Excost.tha
**/

```
  1 exchange costs                                  Subs +Circs
      0.0       0.0       0.0    7780.00  DigitalT (0 +  12000)
  1 exchange sizes
 1. 1.     0. 12000.     0.  DigitalT
DigT
```

/**
Exdefd.GSM
**/

```
13 exchanges
MSC_1     1  0.0    0.0    2  2  2  0      0.      0.
MSC_2     2  0.0    0.0    2  2  2  0      0.      0.
MSC_3     3  0.0    0.0    2  2  2  0      0.      0.
MSC_4     4  0.0    0.0    2  2  2  0      0.      0.
MSC_5     5  0.0    0.0    2  2  2  0      0.      0.
MSC_6     6  0.0    0.0    2  2  2  0      0.      0.
MSC_7     7  0.0    0.0    2  2  2  0      0.      0.
MSC_8     8  0.0    0.0    2  2  2  0      0.      0.
MSC_9     9  0.0    0.0    2  2  2  0      0.      0.
MSC_10   10  0.0    0.0    2  2  2  0      0.      0.
```

```
MSC_11   11  0.0    0.0    2  2  2  0      0.      0.
MSC_12   12  0.0    0.0    2  2  2  0      0.      0.
MSC_13   13  0.0    0.0    2  2  2  0      0.      0.
  4  levels
  1  1  1  1  0  0     Lev1
  2  2  2  1  0  0     Lev2
  3  3  3  1  0  0     Lev3
  4  4  4  2  0  0     Lev4
  3  exchange types
  1  1  1  1  1  1  1  1  2     analog
  1  1  1  2  2  2  2  1  3     dig
  1  3  1  2  3  1  2  3  3     RSU
  3  optimization rules
  1  1
  0  0
  0  0
```

/**

Gos.tha

**/

```
  4  0  GOS matrix
 0.01  0.01  0.01  0.01  0.005
 0.01  0.01  0.01  0.01  0.002
 0.01  0.01  0.01  0.01  0.002
 0.01  0.01  0.01  0.01  0.002
 0.000 0.000 0.000 0.000 0.000
Lev1Lev2Lev3Lev4
```

/**

Links.GSM

**/

```
Format:(2I3,F5.0,I3,2F5.0,2I3,I5,I3,i3)
  1  2 -1.0  1 1.   1.    0  0    0  1  0 MSC_1 MSC_2
  2  5 -1.0  1 1.   1.    0  0    0  1  0 MSC_2 MSC_5
  5  4 -1.0  1 1.   1.    0  0    0  1  0 MSC_5 MSC_4
  4  1 -1.0  1 1.   1.    0  0    0  1  0 MSC_4 MSC_1
  4  8 -1.0  1 1.   1.    0  0    0  1  0 MSC_4 MSC_8
  5  7 -1.0  1 1.   1.    0  0    0  1  0 MSC_5 MSC_7
  7  8 -1.0  1 1.   1.    0  0    0  1  0 MSC_7 MSC_8
  8  3 -1.0  1 1.   1.    0  0    0  1  0 MSC_8 MSC_3
  3  1 -1.0  1 1.   1.    0  0    0  1  0 MSC_3 MSC_1
  5  6 -1.0  1 1.   1.    0  0    0  1  0 MSC_5 MSC_6
  6  9 -1.0  1 1.   1.    0  0    0  1  0 MSC_6 MSC_9
  9  7 -1.0  1 1.   1.    0  0    0  1  0 MSC_9 MSC_7
  9 12 -1.0  1 1.   1.    0  0    0  1  0 MSC_9 MSC_12
 12 10 -1.0  1 1.   1.    0  0    0  1  0 MSC_12 MSC_10
 10  7 -1.0  1 1.   1.    0  0    0  1  0 MSC_10 MSC_7
 12 13 -1.0  1 1.   1.    0  0    0  1  0 MSC_12 MSC_13
 13 11 -1.0  1 1.   1.    0  0    0  1  0 MSC_13 MSC_11
 11 10 -1.0  1 1.   1.    0  0    0  1  0 MSC_11 MSC_10
 11  8 -1.0  1 1.   1.    0  0    0  1  0 MSC_11 MSC_8
        0  0
```

/***

Newexd..tha

***/

```
  4 -1  3 21  new exchanges
  1  2  2  0  Lev1
  2  2  2  0  Lev2
  3  2  2  0  Lev3
  4  2  2  0  Lev4
  1  Z00
  2  A00
  4  B00
  7  C00
  9  D00
 13  E00
 16  F00
 20  G00
 26  I00
 31  J00
 36  K00
 40  L00
 44  M00
 48  N00
 51  O00
 54  P00
 56  Q00
 59  R00
 62  S00
 65  T00
 68  U00
```

/***

Nodes.GSM

***/

```
  1 N  Nodes GSM
Format:(i3,2f5.0,I3,1x,2i3,f5.0,3f6.1,4x,a6)
  1 255.   0.  0.  1  1   0.   0.0   0.0   0.0    M_1
  2   0.  93.  0.  1  2   0.   0.0   0.0   0.0    M_2
  3 352.  74.  0.  1  3   0.   0.0   0.0   0.0    M_3
  4 221. 136.  0.  1  4   0.   0.0   0.0   0.0    M_4
  5 151. 200.  0.  1  5   0.   0.0   0.0   0.0    M_5
  6 153. 347.  0.  1  6   0.   0.0   0.0   0.0    M_6
  7 309. 275.  0.  1  7   0.   0.0   0.0   0.0    M_7
  8 426. 231.  0.  1  8   0.   0.0   0.0   0.0    M_8
  9 284. 440.  0.  1  9   0.   0.0   0.0   0.0    M_9
 10 406. 328.  0.  1 10   0.   0.0   0.0   0.0    M_10
 11 520. 292.  0.  1 11   0.   0.0   0.0   0.0    M_11
 12 356. 452.  0.  1 12   0.   0.0   0.0   0.0    M_12
 13 481. 455.  0.  1 13   0.   0.0   0.0   0.0    M_13
```

/***

Rout.tha

***/

```
  4 routing principles
HHHHH  Lev1
HHHHH  Lev2
```

```
HHHHH  Lev3
HHHDD  Lev4
DDDDD  internal traffic
 -1 -1 -1 -1 -1    Lev1
 -2 -1 -1 -1 -1    Lev2
 -2 -2 -1 -1 -1    Lev3
 -2 -2 -2  0  0    Lev4
  0  0  0  0  0
Lev1Lev2Lev3Lev4
```

/**

Traf.GSM

**/

```
M   Circuit matrix - GSM
   0 600   0   0   0   0   0   0 510   0   0 480   0
   0   0   0   0   0   0 420 480 480 660   0 7801020
   01520   01380   0 720   0 600 600   0   0 900 780
   0   0   0   0 600   0   0 690 690   0 390   0   0
   0   0 142   0   0   0   0   01440   0   0   0   0
   0   0   0 125   0   0   0 990 990   0   0 780 630
   0 555   0   0   0   0   0   0 870   0   0   0   0
   0   0   0   0 300   0   0   0   0   0 390 540   0
 100   0   0 120   0 225   0   01254   0   0 540   0
 500   01230   0   0   0   0   0   0   0   01380   0
 200   0   0   01452   0 545   0   0   0   0   0   0
   0   0 125   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0 142   0   0   01425   0   0   0
```

/**

Transys.tha

**/

```
  7         TRANSMISSION SYSTEMS   (DIGITAL)
DL4   480     30.   7610.   4570.     0.   2  1  1
DL5   960     30.  11090.   6300.     0.   2  1  1
DL61 1920     30.  14780.   6910.     0.   2  1  1
DL62 3840     30.  22810.   8660.     0.   2  1  1
DL63 5760     30.  30540.  10400.     0.   2  1  1
DL7   960      0.   4130.      0.   531.2  2  2  1
*    1920          15980.      0.   153.6  2  2  1
  1
  7  1  2  3  4  5  6  7
  2                    lists of inter-exchange, or exchange-subscriber,
systems
  2                   table of inter-exchange
  1  1
  1  1
  7 systems in table 1 (between exchanges)
  1  2  3  4  5  6  7
  7 systems in table 2 (between NODES AND exchanges)
  1  2  3  4  5  6  7
```

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